Guideline Twelve: Guidelines for Long-Term Monitoring for Epilepsy

Long-term monitoring for epilepsy (LTME) refers to the simultaneous recording of EEG and clinical behavior over extended periods of time to evaluate patients with paroxysmal disturbances of cerebral function. LTME is used when it is important to correlate clinical behavior with EEG phenomena. EEG recordings of long duration may be useful in a variety of situations in which patients have intermittent disturbances that are difficult to record during routine EEG sessions. However, as defined here, LTME is limited to patients with epileptic seizure disorders or suspected epileptic seizure disorders. These guidelines do not pertain to extended EEG monitoring used in a critical care, intraoperative, or sleep analysis setting.

Although LTME can, in general, be considered to be longer than routine EEG, the duration varies depending on the indications for monitoring and the frequency of seizure occurrence. Because the intermittent abnormalities of interest may occur infrequently and unpredictably, the time necessary to document the presence of epileptiform transients or to record seizures cannot always be predetermined and may range from hours to weeks. Diagnostic efficacy requires the ability to record continuously until sufficient data are obtained. Consequently, "long-term monitoring" refers more to the capability for recording over long periods of time than to the actual duration of the recording. The term "monitoring" does not imply real-time analysis of the data.

Developments in digital technology have enhanced the ability to acquire, store, and review data in LTME to such a degree that digital systems are now the industry standard. These guidelines will therefore focus on these systems. It is expected that further advances in digital technology will make it necessary to review these standards on a regular basis.

INDICATIONS FOR LTME

This listing of indications is not meant to be all-inclusive, because special circumstances may warrant additional considerations.

Diagnosis

1. Identification of epileptic paroxysmal electrographic and/or behavioral abnormalities. These include epileptic seizures, overt and subclinical, and documentation of interictal epileptiform discharges. EEG and/or behavioral abnormalities may assist in the differential diagnosis between epileptic disorders and conditions associated with intermittent symptoms because of nonepileptic mechanisms (e.g., syncope, cardiac arrhythmias, transient ischemic attacks, narcolepsy, other sleep disturbances, psychogenic seizures, other behavioral disorders).
2. Verification of the epileptic nature of the new "spells" in a patient with previously documented and controlled seizures.

Classification/Characterization

1. Classification of clinical seizure type(s) in a patient with documented but poorly characterized epilepsy.
2. Characterization (lateralization, localization, distribution) of EEG abnormalities, both ictal and interictal, associated with seizure disorders. Characterization of epileptiform EEG features, including both ictal discharges and interictal transients, is essential in the evaluation of patients with intractable epilepsy for surgical intervention.
3. Characterization of the relationship of seizures to specific precipitating circumstances or stimuli (e.g., nocturnal, catamenial, situation-related, activity-related). Verification and/or characterization of temporal patterns of seizure occurrence, either spontaneous or with respect to therapeutic manipulations (e.g., drug regimens).
4. Characterization of the behavioral consequences of epileptiform discharges as measured by specific tasks.

Quantification

1. Quantification of the number or frequency of seizures and/or interictal discharges and their relationship to naturally occurring events or cycles.
2. Quantitative documentation of the EEG response (ictal and interictal) to a therapeutic intervention or modification (e.g., drug alteration).
3. Monitoring objective EEG features are useful in patients with frequent seizures, particularly with absence and other seizures having indiscernible or minimal behavioral manifestations.

QUALIFICATIONS AND RESPONSIBILITIES OF LTME PERSONNEL

Chief or Medical Supervisor of LTME Laboratory

Qualifications

1. A physician with appropriate qualifications to be chief of an EEG laboratory [e.g., as outlined in *Guidelines for Laboratory Accreditation, Standard I*, published by the American Clinical Neurophysiology Society (ACNS)].
2. Certification by the appropriate national certifying group in EEG.
3. Special training in the operation of LTME equipment,

ISSN: 0736-0258/08/2503-0170

which is typically more complex than that used for routine EEG recording. Special knowledge of the technical aspects of data recording, storage, and retrieval is required, and formal training or equivalent experience in electronics and/or computer science is strongly recommended.
4. Special training in the interpretation of EEG and video data generated in an LTME laboratory. Experience beyond routine EEG interpretation is necessary, since much of the analysis involves complex ictal and interictal features, as well as artifacts, seldom encountered in a standard EEG laboratory. Long-term monitoring systems can use methods of data display or formats of data review (e.g., discontinuous segments). The analysis of LTME data requires as well the simultaneous interpretation and correlation of EEG data and behavioral events.
5. As a minimum, it is recommended that experience in the practical use of specialized LTME equipment and in data interpretation be gained by working in a major LTME laboratory, preferably under the direction of an individual who meets the qualifications for chief or medical supervisor of an LTME laboratory.

Responsibilities

1. The chief or medical supervisor of an LTME laboratory should have the same responsibilities and authority as the chief of an EEG laboratory. They must possess the training and necessary skills needed to care for a person having seizures.
2. Additional responsibilities include the final interpretive synthesis of LTME data with diagnostic and pathophysiological formulations.

LTME Electroencephalographer

Qualifications

1. A physician with the qualifications to be a clinical electroencephalographer (e.g., as outlined in *Guideline Four: Standards of Practice in Clinical Electroencephalography*, published by the ACNS).
2. Specialized training and experience in the use of LTME equipment and in the interpretation of LTME data are necessary, preferably under the direction of an individual who meets the qualifications for chief or medical supervisor of an LTME laboratory.

Responsibilities

Responsibilities include the analysis of, at minimum, pertinent segments of collected electrographic and behavioral data reviewed in all appropriate formats, the writing of LTME reports, and the final interpretive synthesis of LTME data with diagnostic and pathophysiological formulations in the absence or in lieu of the chief or medical supervisor.

LTME EEG Technologist I to III

Qualifications

1. A technologist with the minimal qualifications of an EEG technologist as set forth by the appropriate national body (e.g., as outlined by the American Society of Electroneurodiagnostic Technologists). In the LTME laboratory EEG technologists should be supervised or managed by Registered EEG Technologist (R. EEG T.).
2. Special training in the use and routine maintenance of LTME equipment in the laboratory of employment, with particular emphasis on techniques for monitoring the integrity of data recording.
3. Special training and resultant expertise in the recognition of ictal and interictal electrographic patterns and in their differentiation from artifacts.
4. Special training and resultant expertise in the management of clinical seizures and seizure-related medical emergencies. Successful completion of training in cardiopulmonary resuscitation is necessary.

Responsibilities

1. LTME technologists I to III should have the same responsibilities and authority as EEG technologists. Competencies in EEG and LTME supported by The American Society of Electroneurodiagnostic Technologists are embraced by LTME technologist. (These can be accessed online at http://aset.i4a.com/files/public/EEG_National_Competencies.pdf and http://aset.i4a.com/files/public/LTME_National_Competencies.pdf.)
2. Additional responsibilities include the technical operation of LTME studies (e.g., patient preparation, equipment setup, and data recording). Overall management of these is the responsibility of a technologist III.
3. Under the supervision of the electroencephalographer in charge, data retrieval and reduction operations may be performed and EEG records prepared in a form suitable for interpretation, by LTME technologists II and III. This may include a prescreening of EEG and behavioral data to define segments for later analysis.

Monitoring Technician

Qualifications

1. Special training with resultant expertise in recognition of clinical ictal behavior and interaction with patients during seizures to elucidate specific ictal symptoms.
2. Special training and resultant expertise in aspects of use of monitoring equipment dependent on specific functions of technician.
3. If direct patient observation is involved, special training and resultant expertise in the management of clinical seizures, seizure-related emergencies, and cardiopulmonary resuscitation are necessary.
4. The monitoring technician position is exclusive of the operating room.

Responsibilities

1. Patient observation (direct or several patients at a time via video monitoring) to identify and note ictal events and interact with patients during seizures and to alert appropriate personnel (e.g., physician, EEG technologist, nursing staff) to the occurrence of each seizure.

2. Depending on specific training and requirements, the monitoring technician may also adjust video cameras to keep patient in view and in focus, oversee the adequate function of EEG recording equipment, administer or monitor continuous performance tasks, and otherwise maintain the integrity of the monitoring procedure, calling appropriate personnel to assist when problems occur.
3. Because of the need for continuous observation during most LTME procedures, monitoring technicians provide essential specialized services that do not require the expertise of physicians, nurses, or EEG technologists, but medical and technical personnel must be immediately available when called by the monitoring technician. If the monitoring technicians are the first responders on site, they must possess the training and necessary skills needed to care for a person having seizures.
4. Assess and respond to integrity of digital recording equipment including the integrity of electrodes.

LONG-TERM MONITORING EQUIPMENT AND PROCEDURES

The following is a discussion of the EEG equipment that is available for long-term neurodiagnostic monitoring and the variety of ways it may be used. Unless otherwise stated, these are not meant to be strict requirements, but only guidelines to appropriate usage.

Electrode Types

Scalp

1. Disk
   a. Used for scalp LTME and ambulatory EEG recording
   b. Electrodes should be applied with collodion/gauze for effective long-term results
   c. Electrode with hole in top is best, since it permits periodic refilling with electrode conductant
2. Needle electrodes are not recommended for long-term recordings.

Basal Extracranial Electrode Positioning

1. Sphenoidal locations are used to record epileptiform activity from the mesial or anterior aspects of the temporal lobe in the region of the foramen ovale. Solid needle or wire construction is not recommended; fine flexible braided stainless steel wire, insulated except at the tip, is best and can be used for periods of days to weeks.
2. Other locations, such as nasoethmoidal, supraoptic, and auditory canal electrode positions, have also been used under special circumstances to better record focal discharges; however, the indications for these placements are not well-defined. These electrodes are not recommended for routine use.
3. There is increasing evidence to suggest that earlobe, anterior, or subtemporal electrode placements are, in most cases, as good as sphenoidal electrodes.
4. Nasopharyngeal locations should not be used in LTME because of the resultant irritation and the demonstrate superiority of other electrode positions.

Intracranial

1. Epidural and subdural electrodes are used to record over the surface of the brain. Electrode "grids" are made of small platinum or stainless steel disks that are embedded into soft silastic. Each grid has 4 to 64 contact points, a few millimeters to about 1 cm apart. Grids are placed epi- or subdurally over the cerebral cortex and require a craniotomy. Electrode "strips" consist of a row of disks embedded in silastic, or a bundle of fine wires, each tip of which is a recording point. Strips are usually inserted through a burr hole.
2. Intracerebral or depth electrodes are used to record from within the brain. Procedures and types of electrodes used vary widely. Two major types include rigid and flexible probes. Most probes are "multicontact" with up to 16 recording points arranged along the shaft, constructed of either stainless steel or magnetic-resonance-imaging-compatible metals such as nichrome.
3. Foramen ovale electrodes are used to record from mesial temporal structures without requiring penetration of the skull. A one- to four-contact flexible electrode is placed in the ambient cistern with the aid of a needle inserted through the foramen ovale. These electrodes are not as close to hippocampal structures as intracerebral electrodes and do not allow as large a recording field as grids and strips but detect mesial temporal EEG discharges better than sphenoidal and scalp electrodes. When extracranial recordings are equivocal, foramen ovale electrodes offer a less invasive alternative to a more complete intracranial evaluation or can be used in association with grids and strips. Foramen ovale electrodes may also be constructed from MRI-compatible metals.
4. All intracranial electrodes applications must be used with proper infection control policies and procedures.
5. All intracranial electrodes and interelectrode connectors to LTME equipment must be "anchored" securely or wrapped to the scalp. This is normally done after checking intracranial electrode integrity with a second bandage over that applied by the neurosurgeon.

EEG Amplifiers

1. The following are recommended performance specifications:
   a. Low-frequency response of 0.5 Hz or lower
   b. High-frequency response of 70 Hz or higher
   c. Noise level less than 1 μV rms
   d. Input impedance of at least 1 Mω
   e. Common mode rejection of at least 60 dB
   f. Dynamic range of at least 40 dB.
2. Frequency filters and gain of the recording system should be set up to obtain maximum information, rather

then clean tracings, when these recordings can be modified as necessary upon replay of recorded EEGs.

EEG and Video Recording/Storage and Retrieval/Review

The method of EEG recording/storage has changed from analog to digital equipment. Please refer to Guideline Eight for recording clinical EEG in digital media.

1. For LTME, digital equipment must be able to record a minimum of 24 hours of Video and 32 to 64 channels of EEG. However, the capacity for 128 channels or more are found in the majority of LTME recording equipment.
2. Storage systems should normally support 24 hours of Video/EEG.
3. The retrieval and review systems should be capable of storing a minimum of 30 gigabytes or 24 hours of Video/EEG. Review can be performed on the same LTME monitoring equipment but a separate system is recommended for physician review as clinical circumstances often make more than 24 hour recording necessary. In either case, all data should be reviewed before any pruning and archiving of data.

EQUIPMENT AND PROCEDURES FOR LTME OF BEHAVIOR AND CORRELATION WITH EEG

A major objective of LTME is the correlation of behavior with EEG findings. Systems should allow the marking of relevant evens by patients or other observers and annotation of the tracing by staff. Behavioral and EEG data are truly complementary. Bizarre ictal behaviors that are not easily recognized as seizures are appropriately identified by a simultaneous epileptiform discharge on EEG. Conversely, video evidence of classic behavioral manifestations of a seizure may be sufficient to diagnose epilepsy even in the absence of a clearly defined epileptiform EEG abnormality during such an episode.

A variety of techniques for behavioral monitoring and its correlation with EEG may be used. This section will discuss the advantages and disadvantages of each and provide recommendations as to their proper use.

Types of Behavioral Monitoring

1. Self-reporting
   a. Features—a daily diary or log in which the patient notes the occurrence of behavioral episodes in question. This is the principal form of behavior monitoring in ambulatory EEG recording and an adjunct to in-patient LTME. A more advanced form of self-reporting includes the use of a pushbutton event marker on the ambulatory EEG recorder or by the bedside for the patient to signal the occurrence of an episode.
   b. Advantages—simple, requires little special equipment, easy to implement, practical way to monitor patients with infrequent seizures for which they have warning or memory. When used with ambulatory recordings, it can provide information regarding the effect of circadian cycles, environmental factors, and antiepileptic drug fluctuations on seizure activity.
   c. Disadvantages—correlation is subjective, record of behavior not available for detailed visual analysis, temporal correlation may be inaccurate even when event marker is used, not possible with seizures for which the patient has no warning or memory, ictal descriptions usually not obtained, not suitable for final correlation in a presurgical workup, but, with 16- to 24-channel ambulatory recording. It may provide preliminary data that can minimize inpatient monitoring.
2. Observer reporting
   a. Features—observer reporting complements self-reporting in daily diaries. Observer reporting by trained hospital personnel can be objective and includes the use of standardized checklists of information to be recorded, direct interaction with the patient to assess mental function (level of consciousness, language function, and memory) and neurologic deficits. A pushbutton event marker, activated by a family member, friend, or LTME staff, can provide temporal correlations of clinical episodes on ambulatory or in-patient EEG recordings. This is a major form of behavior monitoring in ambulatory EEG recording, particularly in young children or in mentally retarded patients who cannot reliably self-report. It is also used in in-patient settings when personnel are available to monitor patient activity.
   b. Advantages—simple and inexpensive, requires little specialized equipment, easy to implement interactive assessments provide critical information about functional deficits accompanying episodes. Since it can be used with seizures for which the patient has no warning or memory, it provides a practical way to monitor patients with infrequent seizures.
   c. Disadvantages—correlation is subjective, record of behavior not available for detailed visual analysis, temporal correlation may be inaccurate even when event marker used, not sufficient for presurgical evaluations. Seizures may be missed if observer is not continuously observing patient.
3. Video recording
   a. Features—principal and most effective means of behavior monitoring in in-patient setting. Patient behavior is continuously recorded on video simultaneously with EEG (vEEG). Observations of LTME personnel, self-reporting by patients, or automated computer analysis of EEG identify episodes that are potentially seizures that require detailed analysis. Direct assessment of neurologic function of patient by LTME staff adds to other recorded data. A succinct event list can be posted for physician review of events and patient push buttons.
   b. Advantages—objective record of behavior, available for replay and associated direct EEG correla-

tion, temporal correlations accurate when synchronization achieved with time code generators or same tape recording, useful in seizures of all types even if minimal behavioral manifestations are initially unrecognized, since permanent record allows subsequent review of behavior associated with EEG changes. The interaction between monitoring personnel and the patient, when properly structured, defines the events more explicitly than other mechanisms.

c. Disadvantages—specialized equipment required, can be time-consuming to implement. When recording without personnel present, interactive assessments of neurologic function are unavailable. A major problem is that freedom of movement is limited by the necessity for the patient to stay in view of the camera.

4. Polygraphic and reaction time monitoring. A variety of approaches can be used to record aspects of ictal behavior along with the EEG. Monitoring of specific physiological functions such as eye movement of electromyography (EMG) may provide useful information for characterizing the behavioral manifestations of ictal events. Cognitive disturbances can be documented by reaction time tasks, with stimulus and response times recorded on an event marker channel. This technique can also be used to demonstrate the discharges that would ordinarily be thought of as interictal can interfere with cognitive processing on a transient basis. Selection of appropriate tasks that can be maintained for prolonged periods, recorded, and quantified allows time indexing to the EEG, and, in essence, may extend the definition of what is ictal for a given patient. LTME personnel should test awareness, memory, language, and gross motor function using a standard protocol during ictal events.

Equipment—Behavioral Data Acquisition

1. Video cameras
   a. Standard monochrome (black and white)—requires illumination of 0.5 footcandle, satisfactory for daylight monitoring conditions, unsatisfactory for nocturnal monitoring under reduced lighting conditions.
   b. Low-light level monochrome—allows monitoring in only 0.03 footcandles of illumination, particularly sensitive to red light, useful for nocturnal monitoring under reduced lighting conditions, automatic iris needed to compensate for sudden increases in light level, especially focal, which can cause "blooming."
   c. Silicon intensified target ("starlight")—effective in as little as 0.000025 footcandles of illumination, image intensifier technology, high resolution for nocturnal monitoring, expense is substantial, value for increased resolution is not established.
   d. Color, current preferred technique—requires 25 footcandles of illumination, better resolution of facial features than black and white, valuable for perceiving certain autonomic changes (e.g., blushing, pallor), not suited to nocturnal monitoring but continuous auto-white balance improves resolution during changes in ambient light, exclusive color systems may be impractical.
   e. Low-light level color—requires 1 to 10 footcandles of illumination, can be used for nocturnal monitoring with small night light, increased expense, value not established in nocturnal conditions except to attempt exclusive use of color cameras.
   f. Solid-state sensor monochrome—longer lasting than tube cameras, good resolution, no "blooming" and no image retention ("burn in"), tolerates difficult lighting conditions, is available with built-in infrared illuminators for night monitoring.
2. Video camera lenses—irises
   a. Standard—iris requires manual adjustment for changing light conditions, inconvenience may lead to neglect of this factor, minimally acceptable for LTME.
   b. Automatic—iris automatically adjusts to changing light conditions, facilitates prolonged monitoring under varying conditions, "blooming" may still occur with a sudden focal increase in light (such as from a match), manual override can compensate for unusual light conditions.
3. Video camera lenses—field of view
   a. Standard—size of viewing field fixed relative to distance between camera and object.
   b. Fixed wide-angle—increases the area monitored at the expense of detail, patient more easily keep within field of view.
   c. Remote zoom—allows personnel to obtain close-up view of area of particular interest (e.g., motor onset of simple partial seizure), uses separate 6-V AC power unlike 24-VAC power to camera and remote pan/tilt.
   d. Remote zoom wide-angle—allows variable area to be monitored depending on clinical situation, 15-mm focal length preferred.
4. Video camera mobility
   a. Fixed position camera—requires that the patient remain within the camera's unchangeable field of view; this degree of restriction of patient mobility difficult to maintain over long monitoring periods, particularly if close-up of face is required.
   b. Mobile or portable camera—provides a changeable field of view to allow some patient mobility, necessitates intrusion into monitoring room, and physical repositioning of camera by personnel for each change.
   c. Remote pan/tilt device—allows personnel to keep patients in view of the camera as they move about the room by moving camera side to side or up/down; recommended for permanent monitoring rooms, separate remote control panel may activate combined focus, zoom, and pan/tilt functions of camera.
5. Audio—microphones. In addition to the video image of patient behavior, it is important to have an audio record of clinical episodes, which includes not only the pa-

tient's verbalizations, but also a description of behavior and neurologic function as assessed and related by LTME personnel attending to the patient during the episode.

a. Unidirectional—picks up only sound coming from directly in front of the microphone head, eliminates extraneous noise, requires readjustment with patient movement, usually attached to video camera, which is aimed at patient, unsatisfactory for recording nearby LTME personnel.
b. Omnidirectional—picks up sound in roughly a spherical distribution around the microphone, eliminates need for directional readjustment, subject to interference from extraneous sounds, recommended as a minimal standard.
c. Pressure zone—mounts to flat surfaces for reduced echo-reverberation, but picks up extraneous sound; discrete and less vulnerable to handling.
d. Sound mixer—combines multiple audio sources into a single signal for recording on videotape; unidirectional and omnidirectional microphone inputs may be combined to obtain improved audio recording capability.

Equipment—Behavioral Data Storage and Retrieval

1. Digital Storage—This is the current industry standard for LTME. Digital storage provides more reliable storage with no degradation of copies. Sufficient storage space to allow for 24 hours of continuous video-EEG information is essential.
2. Display monitors
   a. Monochrome—perceived optical resolution is 525 line pairs, satisfactory for LTME, higher optical resolution of up to 1,000 line pairs available in some monitors.
   b. Color—perceived optical resolution of 250 line pairs, minimal acceptable standard for LTME. The current optimal standards are 1,600 × 1,200 pixels with a screen diagonal size of 20 inches or more.

Behavioral Data Storage Protocols

1. Storage for initial analysis
   a. All video/audio monitoring data as well as associated EEG recordings should be saved until appropriately analyzed and reduced by trained personnel.
   b. When long-term monitoring is only for the purpose of recording clinical episodes, partial data reduction can be performed online. Data containing no episodes may be erased.
   c. If a clinically significant event has occurred, the data should be retained for later analysis.

2. Archival storage
   a. When it has been determined on analysis that a behavioral episode is clinically relevant, video-recorded data should be copied onto a durable medium for long-term storage.
   b. Edited data to be stored should include a short period (approximately 2 minutes) before and after the event, as well as the entire episode. A log of the contents of all edited data should be maintained, preferably as part of the detailed report.

Behavioral Data Analysis and Correlations with EEG

1. Event analysis
   a. Using the appropriate review options, a detailed characterization of the temporal sequence of the patient's behavior during each clinical episode should be accomplished under the direct supervision and review of the LTME electroencephalographer.
   b. Attention should be paid to the sequence and character of motor activity, verbalizations, responsiveness to stimuli, and any other noteworthy features.

2. Correlation of behavior and EEG
   a. EEG that is temporally concurrent with the clinical episode in question should also be analyzed in detail for significant change of progression in pattern, with particular emphasis on those that are ictal in character.
   b. The progression of behavioral alterations as outlined in the event analysis can be correlated to any EEG changes by using synchronous time codes recorded on each. Times codes should be accurate to less than 0.5 seconds.

TECHNICAL AND METHODOLOGICAL CONSIDERATIONS

Electrode Locations

1. Use of the International 10–20 System with supplementary positions is suggested to maintain standardization. Additional electrodes are often helpful in the evaluation of patients for epilepsy surgery.
2. Atypical electrode positions such as F9, F10, and Nz (nose tip), as well as special electrodes such as sphenoidal may be used depending on the clinical indications.
3. Intracranial electrode placements (epidural, subdural, intracerebral, and foramen ovale) are used in candidates for surgical resection of an epileptic lesion. They are indicated to answer specific questions about the localization of discharges determined to be of focal origin by surface-recording techniques, but insufficiently defined to direct surgical interventions. Use of nonferrous metals such as platinum and nichrome allows MRI verification of electrode location. In these instances of intracorporeal recording sites, the guidelines for patients with in-dwelling devices should be followed in the United States (UL, Type A patient). They are not appropriate when surface EEG recordings provide no clues to the presence or location of a focal lesion. Because of the diversity of the techniques in use, specific recommendations concerning electrical and

mechanical safety precautions are beyond the scope of this discussion.

Electrode Application/Insertion

1. Disk—Collodion technique is currently the only method that will insure a stable long-term recording. Application by electrode paste alone is not recommended. Collodion should be dried slowly to make a film over the electrode, which prevents the electrode jelly from drying out. This may be facilitated by the use of pressured air. Underlying skin should not be unduly abraded when electrodes are to remain in place several days. Electrode jelly that is used should not contain irritants or dry out quickly. A felt pad may be used under a disk electrode to prevent pressure breakdown of the skin.
2. Sphenoidal—inserted bilaterally through the skin below the zygomatic arches in the direction of the foramen ovale by an electroencephalographer or qualified physician, with or without local anesthetic. Flexible wire electrodes are placed 3 to 4 cm deep, within or alongside a needle, and the needle is then removed. The external wire should be coiled, to relieve tension, and fixed to the cheek with collodion and/or tape at the point of exit from the skin.
3. Epidural and subdural—inserted during a neurosurgical procedure. Epidural and subdural electrode grids are directly placed over accessible areas of the cerebral cortex through a craniotomy. Strip electrodes are usually placed freehand through burr holes.
4. Intracerebral—inserted stereotactically into bilateral temporal and/or extratemporal sites.
5. Foramen ovale—inserted bilaterally through the skin using an approach similar to that for percutaneous trigeminal rhizotomy, by a qualified neurosurgeon. A 1–4-contact flexible electrode remains in the ambient cistern after the insertion needle is withdrawn.

Electrode Maintenance

1. Disk-recording characteristics of electrodes should be checked every day so that electrode contact deterioration can be detected and corrected without interruption of the recording. Impedance should be checked periodically, and if recording characteristics change. Refilling of the electrodes with conductant gel should be performed as necessary to maintain low impedance. If electrode conductant is applied via blunted tip syringes; they are appropriately disposed of after each use.
2. Sphenoidal—care must be taken to relieve stress on the recording wires. External wires should be inspected periodically to insure proper fixation to the skin and minimize the possibility of breakage or accidental removal. Inspect that the tip of sphenoid is still intact and that the length of the sphenoid is the same as the length of sphenoid upon insertion.
3. Epidural, subdural, intracerebral, foramen ovale—once inserted for chronic recording, electrode malfunction cannot be corrected, although its condition can be assessed through the quality of the recording. The special connectors used with these electrodes are liable to cause problems and must be inspected periodically.

Electrode Impedance

1. Disk-impedance should be measured at the beginning, periodically during, and with ambulatory EEG at the end of the recording. Initial impedance should be less than 5,000 ohms. During in-patient LTME, attempts should be made to maintain this level.
2. Sphenoidal—impedance can be measured in routine fashion and maybe of help in verifying the cause of a change in recording characteristics.
3. Epidural, subdural, intracerebral, foramen ovale—impedance measurements can be safely performed with currents in the range of 10 nA for electrodes inserted intracranially. This is 1,000 times less voltage than the normal 5 to 10 kohm impedance measurements of scalp electrodes. Care must be taken not to polarize intracerebral electrodes. Electrode conductivity and integrity of insulation should be checked before sterilization of the electrodes.

Digital Equipment and Calibration

Digital Equipment and Calibration are Addressed in Guideline 1

Before beginning LTME and periodically during the monitoring, the integrity of the entire recoding system from electrode to storage medium should be checked by observing ongoing EEG, tapping electrodes or connectors, and/or by having the patient generate physiological artifact. The resultant signals should be examined online and offline and compared with baseline recordings.

Recording Techniques

1. Number of channels—standard LTME
   a. Telemetered EEG long-term monitoring requires a minimum of 16 channels, similar to the guideline for routine clinical EEG.
   b. A large number of EEG channels is essential for obtaining accurate localization, as is required in a presurgical evaluation. Thirty-two- to 64-channel recordings are recommended for this purpose.
2. Number of channels—ambulatory EEG
   a. Fewer than eight EEG channels are usually not sufficient for a primary EEG evaluation.
3. Montages—extracranial recordings
   a. Montages should be appropriate for the abnormalities anticipated and should be determined on the basis of previously documented EEG findings. Guidelines for montages can be found in other ACNS guidelines. An important aspect of montage design for LTME is to clearly separate activity from the basal temporal electrodes from the remainder of the standard 10 to 20 derivations.
   b. Simultaneous ECG recording is recommended, since cardiac arrhythmias may produce artifacts that mimic epileptiform EEG transients.

4. Montages—intracranial recordings
   a. Montages depend on the type and location of the implanted electrodes.
   b. Common approaches include linking adjacent contact points in a linear bipolar chain to survey a large area, defining well a small area with closely spaced bipolar derivations or referring all contact points to a least active point to obtain a referential recording.
   c. Montages may include some scalp derivations to assure adequate characterization of abnormalities.
5. Montages—ambulatory EEG
   a. Montage selection for a given patient should be guided by previously documented abnormalities on routine EEG and by clinical history. Guidelines for montages can be found in other ACNS guildelines.
6. Use of filters and sensitivity—EEG signals
   a. Low linear filters and sensitivity settings should be adjusted to optimize review, but it is best to record information in as wide a frequency band as possible and selectively filter the signals, as necessary upon playback.
   b. Filter settings in most cases are the same as those used in standard laboratory EEG, i.e., high linear frequency filter of at least 70 Hz, but preferably higher, and a low linear frequency filter at 0.5 to 1 Hz. More selective filtering may enhance the information obtained from intracranial recording.
   c. Certain environments may require the use of a 50 to 60-Hz notch filter. This should only be applied after inspection of the recording without a notch filter to detect electrode artifacts. Under certain unavoidable conditions, more restrictive filtering than that above may improve the recording.
   d. Sensitivity settings for extracranial recording should be equal among channels and follow the recommendations for routine EEG. For intracranial recordings, equal sensitivity settings are recommended, if possible, as when using equally spaced chain linkage bipolar or common reference montages. Sensitivity can be set independently for each channel to obtain the best relative signal when closely or irregularly spaced bipolar intracerebral derivations are used.
7. Monitoring of other physiological parameters
   a. Recording of the ECG, electrooculogram, EMG, or respiration may be indicated for particular clinical situations. Recording techniques are the same as in standard polygraphy.
   b. In ambulatory EEG systems, the use of more than one channel for other physiological monitoring may limit the usefulness and validity of the EEG data.

Artifacts

The differentiation of artifacts and normal EEG transients from EEG abnormalities poses an increased problem in LTME, particularly in ambulatory EEG recordings with a limited number of channels. Unusual artifacts not seen in standard laboratory EEG recording are commonly encountered.

1. Biologic
   a. In addition to the normally recognized eye movements, blinking, muscle tension, ECG, respiration, sweating, and tremor, activities such as chewing, talking, and teeth brushing can produce EMG, glossokinetic, and/or reflex extraocular movement potentials and result in potentially confusing patterns.
   b. Standard disk electrode recordings are very susceptible to biologic artifact. Sphenoidal electrodes are associated with less artifact. Intracranial electrode recordings are usually free of biologic artifacts, except for pulsation.
2. Mechanical or external
   a. The main mechanical artifacts of telemetry originate from altered electrode/scalp contact or intermittent lead wire disconnection induced by body movement. Direct connection with standard cable imposes additional artifacts from movement of the cable itself.
   b. Artifacts produced by rubbing or scratching of the scalp and other rhythmic movements of head or extremity can, in association with accompanying biologic artifact, result in particularly confusing patterns that must be differentiated from ictal discharges.
   c. The most common external artifact in surface recordings is 50- or 60-Hz interference. Electromagnetic fields due to nearby fans, air conditioning, or ballasts of fluorescent lights and vertical alignment of LTME power cable and pneumonic pressure boots can produce interference of 50- or 60-Hz plus harmonics. A crossing of cables can eliminate some artifact interference. Electrostatic potentials due to nearby movement of persons with dry clothing or telephone ringing may produce spurious transients.
   d. In intracranial recording, mechanical artifacts due to body movement are usually negligible and those due to electrical interference are usually less than with extracranial electrodes.
3. Instrumental
   a. Any part of the recording and playback system, e.g., electrodes, wires, amplifiers, can be a source of artifact.
   b. Common sources of spurious transients are electrode popping, faulty switches or connectors, or touching of dissimilar metals. Rhythmic slow waves can be due to chipped silver—silver chloride coating, instability of the electrode scalp interface, and electrode wire movement.
4. Recognition/interpretation
   a. A conservative interpretation of unusual or equivocal EEG events is mandatory in LTME, particularly in instances in which the patient's activity at that moment cannot be verified for possible artifact production.
   b. Personnel should familiarize themselves with the common artifacts of active wakefulness and EEG transients of normal sleep. Recognition of the in-

strumental artifacts of a particular laboratory or recording arrangement is equally necessary to insure reliable differentiation from cerebrally generated events.
c. In ambulatory EEG monitoring, all common biologic and mechanical artifacts should be produced by the patient and/or technologist at the beginning or the end of the recording, where they can serve as a reference for confusing transients noted on review of that particular tape.
d. When simultaneous video-recorded behavior is available, artifacts due to biologic and mechanical disturbances, particularly rhythmic ones, can usually be verified by review of the videotape.
e. When patient behavior is not being video recorded, identification of a rhythmic discharge as an epileptic seizure can be made by recognition of well-formed epileptiform spike-and-wave patterns with a believable field and typical ictal progression (for partial and convulsive seizures, the ictal discharge usually begins with low-voltage fast activity and becomes slower with higher amplitude), as well as postictal slowing, appropriate interictal abnormalities in other portions of the record, and an appropriate episode noted in the patient's diary or by an observer.
f. Interictal epileptiform EEG abnormalities should be identified as recurrent independent transients in artifact-free portions of the record, such as quiet wakefulness or sleep. Sharp waveforms noted only during active wakefulness should be interpreted as abnormal with caution.

LTME Quality Assurance

Periodic checking of the status of ongoing EEG recording is essential and should be performed at least once a day.

RECOMMENDED USES OF SPECIFIC LTME SYSTEMS

Although the large numbers of different EEG and behavior monitoring components create the possibility of many combinations that could comprise an LTME system, there are only a small number of configurations in general use. Listed below are recommended basic system configurations along with indications (refer to Section II) for which each is appropriate and not appropriate. Combinations of these systems are commonly used.

Monitoring With Continuous Storage of Video and EEG Data

1. EEG transmission—most often achieved using cable connection or radio telemetry
2. EEG recording/storage—mostly often acquired using digital systems
3. EEG review/analysis—review of all episodes and random samples of background, although complete review of all EEG data is possible
4. Behavior monitoring—self, observer, and video
5. Clinical indications
   a. Appropriate—documentation, characterization, and quantification of clinical ictal episodes and their EEG features over days to weeks and assessment of their relationships to behavior, performance tasks, naturally occurring event or cycles, or therapeutic intervention.
   b. Comment—at least 16 channels of EEG data and synchronized video monitoring are required for presurgical localization of epileptogenic regions.
   c. Not appropriate—for the quantitative analysis of subclinical ictal or interictal features and for evaluation benefiting from complete freedom of movement.

Computer-Assisted Selective Monitoring

1. EEG transmission—cable or radio telemetry
2. EEG recording/storage—digital tape/disk, computer-assisted selective storage
3. EEG review/analysis—selective analysis of clinical and computer-recognized ictal and interictal events
4. Behavior monitoring—self, observer, and video
5. Clinical indications
   a. Most appropriate—documentation, characterization, and quantification of ictal (clinical and subclinical) and interictal EEG features and assessment of their relationship to behavior, performance tasks, naturally occurring events or cycles, or therapeutic intervention.
   b. Comment—computer recognition programs have not been perfected and are subject to a variable amount of false-negative and false-positive error. At least 16 channels of EEG data and synchronized video monitoring are required for presurgical localization of epileptogenic regions. Radio telemetry provides more mobility than cable telemetry; however, video monitoring becomes difficult or impossible when this degree of mobility is required.
   c. Not appropriate—evaluations benefiting from complete freedom of movement.

Ambulatory Continuous EEG Recording

1. EEG transmission—ambulatory
2. EEG recording/storage—digitally stored
3. EEG review/analysis—events reviewed in detail, random samples of EEG analyzed
4. Behavior monitoring—self report, observer log comments
5. Clinical indications
   a. Appropriate—documentation and quantification of ictal (clinical and subclinical) and interictal EEG features and assessment of their relationship to reported behavior.
   b. Comment—also applicable in an in-patient setting, particularly when mobility is of benefit.
   c. Not appropriate—detailed characterization of EEG features as is required in presurgical evaluation.

Ambulatory—Selective, Computer Assisted

1. EEG transmission—ambulatory (16–24 channels)
2. EEG recording/storage—digitally stored
3. EEG review/analysis—selective analysis of computer-recognized ictal and interictal events
4. Behavior monitoring—self, observer
5. Clinical indications
   a. Appropriate—same as C, except that seizures without an obvious behavioral change may be detected
   b. Comment—same as C
   c. Not appropriate—same as in C

Minimum Standards of Practice for Specific Indications

When in-patient LTME is performed, an EEG technologist, monitoring technician, epilepsy staff nurse, or other qualified personnel must observe the patient, record events, and maintain recording integrity.

Presurgical Evaluations

The most exacting evaluation in LTME is the attempt to localize, by means of surface and/or intracranial electrodes, a region of epileptogenic brain tissue that is the site of origin of recurrent seizures and that is amenable to surgical removal. The following are minimum acceptable standards.

1. EEG transmission—standard cable ("hard wire") or telemetry EEG with at least 16 channels of EEG data. Cable telemetry is the most common technology. Ambulatory EEG is not acceptable for final evaluation, but may serve a useful triage function.
2. EEG recording storage—continuous digital storage with synchronization of video data.
3. EEG review/analysis—detailed visual analysis of all seizures and representative interictal abnormalities from a high-quality display is required. Additional computer analyses of EEG abnormalities (temporal and distribution characteristics) may be beneficial.
4. Behavior monitoring—continuous video recording with a time code synchronized to EEG. Observer or self-reporting of behavior is not sufficient. Time-lapse video recording is discouraged.

Diagnosis of Nonepileptic Seizures

Minimum standards of practice in the differentiation of nonepileptic seizures from epileptic seizures are the same as above, although eight channels of EEG data can be adequate to identify most epileptic events. Regardless of the number of channels, however, absence of clear ictal EEG abnormalities during a behavioral event must be interpreted with reference to the complete clinical evaluation before a diagnosis of nonepileptic seizures can be made.

Classification and Characterization of Epileptic Events

Only systems with 18 or more channels (16 EEG, 1 eye, and 1 EKG) can provide basic characterization of epileptic EEG events.

GUIDELINES FOR WRITING REPORTS ON LTME

General Considerations

1. The LTME report should consist of four principal parts.
   a. A statement of the clinical problem and overall intent of LTME background information should include a brief summary of the clinical history and physical findings, the reasons for referral and a brief review of current medications and other existing conditions that might alter recorded EEGs or behavior. The purpose of the LTME (e.g., diagnostic study, presurgical evaluation) should be clearly stated.
   b. An explanation of technological aspects of the recording, such as number of channels of EEG recorded, type and location of electrodes (e.g., scalp, sphenoidal, intracranial, multiple EMG, ECG), and the use of manual and/or automated seizure and/or discharge detection should be documented. Special observations (oximetry, sleep assessment, blood pressure, or cardiac arrhythmia monitoring) are indicated. Activation procedures (drug injection, suggestion, hyperventilation, exercise, re-enactment of precipitating events), testing of reaction times, etc., should be fully described. The reduction of medications, especially those intended to increase or decrease the incidence of seizures, is described.
   c. A description of the findings should include a statement concerning waking and sleeping EEG patterns, magnitude and location of nonepileptiform abnormalities, and the presence of artifacts that might reflect on the overall quality of the recording. The frequency of occurrence, character, topographic distribution, and propagation of interictal epileptiform discharges should be reported. Behavioral and electrographic ictal events should be emphasized and described in detail. Descriptions of patient behavior should include portrayal of activity immediately preceding the attack, characteristic features of the onset, course, and termination of the episode, and ictal and postictal behavior evident spontaneously, as the result of examination, and as supplemented by reports of observers. Specifically, responsiveness, orientation, language, memory, motor activity, and other neurologic functions are to be reported. The electrographic findings to be reported should include descriptions of background activity and epileptiform discharges preceding the seizure, the mode, pattern, and location of onset of ictal activity, the propagation and termination of seizure discharges, and postictal changes. The durations, relative times of onset, and significant changes in clinical and electrographic ictal events should be presented. The temporal relationship between behavioral manifestations and ictal electrographic events should be noted.
   d. An interpretation, stating the overall impressions gained from, and clinical significance of, the electrographic and behavioral correlations. This portion of the report should be an interpretive synthesis rather than a reiteration of the description. Seizures and

epilepsy syndromes should be classified wherever possible according to the guidelines developed by the International League Against Epilepsy. Overall pathophysiological and diagnostic formulations should include reference to available data on the quantitative and topographic features of interictal epileptiform and nonepileptiform, as well as ictal, abnormalities. Inferences as to the site of origin and propagation of seizures should be made when this is justified by the findings. Suggestions for subsequent studies are stated.

This Guideline was reviewed and revised by Richard P. Brenner, M.D., University of Pittsburgh Medical Center, Pittsburgh, PA; Frank W. Drislane, M.D., Beth Israel Deaconess Medical Center, Newton, MA; John S. Ebersole, M.D., University of Chicago, Chicago, IL; Madeleine Grigg-Damberger, M.D., University of New Mexico, Albuquerque, NM; Mark Hallett, M.D., National Institute of Health, Bethesda, MD; Susan T. Herman, M.D., University of Pennsylvania Health System, Philadelphia, PA; Lawrence J. Hirsch, M.D., Columbia University, New York, NY; Aatif M. Husain, M.D., Duke University Medical Center, Durham, NC; Peter Kaplan, MB, FRCP, John Hopkins Bayview Medical Center, Baltimore, MD; Alan D. Legatt, M.D., Ph.D., Montefiore Medical Center, Bronx, NY; Douglas R. Nordli, Jr., M.D., Children's Epilepsy Center, Chicago, IL; Gareth J. Parry, M.D., University Minneapolis, Minneapolis, MN; Mark A. Ross, M.D., Mayo Clinic, Scottsdale, AZ; Donald L. Schomer, M.D., Beth Israel Deaconess Medical Center, Hingham, MA; Elson Lee So, M.D., Mayo Clinic, Rochester, MN; Austin J. Sumner, M.D., LSU School of Medicine, New Orleans, LA; William O. Tatum IV, D.O., University of South Florida, Tampa, FL.