GUIDELINE

American Clinical Neurophysiology Society Guideline 1: Minimum Technical Requirements for Performing Clinical Electroencephalography

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Although no single best method exists for recording EEGs under all circumstances, the following standards are considered the minimum for the usual clinical recording of EEGs in all age groups except the very young (see also Guideline 5: *Minimum Technical Standards for Pediatric Electroencephalography*. Sections where modifications are recommended are delineated by ^for neonates and *for older children).

This document discusses minimum requirements; following these requirements alone does not ensure a satisfactory test. Each laboratory should strive for excellence in all aspects of study performance. Recommendations to improve standardization of procedures and to facilitate interchange of recordings and assessment among laboratories in North America have also been included. More detail is provided in recommendations from the International Federation of Clinical Neurophysiology (IFCN).[1]

1. EQUIPMENT

1.1 ^To display the distribution of EEG activity, it is necessary to record simultaneously from as many regions of the scalp as possible. When too few channels are used, the chances of interpretive errors increase; conversely, when more channels are used, the likelihood of such errors decreases. This is particularly true for transient activity.

Sixteen channels of simultaneous recording are considered the minimum number required to show the areas producing most normal and abnormal EEG patterns.

Additional channels are often needed for monitoring other physiologic activities and for highlighting activity recorded in specific regions.

1.2 Alternating current (AC) wiring should meet the Underwriters Laboratories standards required for hospital service, as per state and local electrical codes.

1.3 In the usual clinical setting, electrical shielding of the patient and equipment is not necessary, and such shielding need not be installed unless proven necessary.

1.4 Ancillary equipment should include a device for delivering rhythmic, high-intensity flash stimuli to the patient.

1.5 Digital EEG equipment should be used for recording. Digital equipment provides multiple advantages over paper-based EEG recording amplifiers, including greater sensitivity, greater reliability, the possibility of postrecording modification of EEG waveform rendering (gain, filters, montage), and more efficient EEG storage. Digital equipment should conform to the recommendations in Guideline 4: *Recording Clinical EEG on Digital Media*.

2. ELECTRODES

2.1 ^*Recording electrodes should be free of inherent noise and drift. They should not significantly attenuate signals between 0.5 and 70 Hz. Experimental evidence suggests that silver—silver chloride or gold disk electrodes held on by collodion are the best, but other electrode materials and electrode pastes have been used effectively, especially with contemporary amplifiers having high-input impedances.

Electrodes must be disinfected with appropriate procedures and transmission-based precautions taken after recording from patients with contagious diseases (e.g., viral hepatitis, Creutzfeldt–Jakob disease, acquired immunodeficiency syndrome).[2] Disposable electrodes may be considered as another option for reducing the risk of iatrogenic infections.

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2.2 Needle electrodes are not recommended for routine clinical use. Beyond considerations of patient discomfort and risk of injuries to personnel, these electrodes have higher impedances than appropriately applied cup electrodes, resulting in potentially higher levels of noise. Subdermal needle electrodes (SNE) or wire electrodes (SWE) may be used for prolonged recording of EEG in stuporous or comatose patients in situations where application of cup electrodes is not feasible because of personnel or time constraints. Although impedances are usually higher, they are usually well-matched and stable over long recording periods. Manufacturer's recommendations for insertion, removal, and disposal of each product are available and should be followed.

2.3 ^All 21 electrodes and placements recommended by the IFCN[3] should be used. The 10 to 20 System is the only one officially recommended by the IFCN. It is the most commonly used system and should be used universally. The use of the term "modified 10 to 20 System" is undesirable and misleading when it means that head measurements have not been made and placements have been estimated. In this case, the term "estimated 10 to 20 placement" is more appropriate. The term "10 to 10 System" should be used for the extended combinatorial system described in Guideline 2: *Guidelines for Standard Electrode Position Nomenclature* (For neonates, refer to Guideline 5). With some differences in naming, electrodes in the 10 to 20 System are included in the 10 to 10 System (T3 and T4 in 10–20 system are renamed T7 and T8 in 10–10 system; T5 and T6 in 10–20 system are renamed P7 and P8 in 10–10 system).

An adequate number of electrodes are essential to ensure that EEG activity having a small area of representation on the scalp is recorded and to analyze accurately the distribution of more diffuse activity. A smaller number of electrodes may be appropriate for special circumstances but is not considered comprehensive. Occasionally, additional electrodes, placed between or below those representing the standard placements, are needed to record localized activity better. The 10 to 10 System provides a standardized option for selecting additional electrodes.

In every case, an isolated ground electrode should be placed and connected to the jackbox as specified by the manufacturer. The isolated ground does not allow dangerous currents to pass and is not a safety hazard as were earth grounds used in early analog EEG devices. No electrode should ever be connected to the chassis of the equipment or to the earth ground. In addition, most digital equipment requires one or more system reference electrodes. These should be placed as suggested by the manufacturer.

2.4^*Interelectrode impedances should be checked as a routine prerecording procedure. With modern digital EEG recording equipment, impedances up to 10 k Ohms are acceptable,[4] but optimal recording still requires impedances that are balanced.[5] Unbalanced impedances compromise the ability of an EEG amplifier to reject potentials that are the same at a pair of electrodes while amplifying those that are different (common mode rejection). Impedances should also not be below 100 Ohms because this usually indicates a shunt or short circuit, possibly related to a salt bridge on the scalp.

Electrode impedances should be rechecked during the recording when any pattern that might be artifactual appears. Still, artifacts may appear even in electrodes with acceptable impedances. Thus, a normal impedance in an electrode demonstrating noise may still indicate the need to change or modify that electrode.

3. RECORDINGS

Montages should be designed in conformity with Guideline 3: *A Proposal for Standard Montages to Be Used in Clinical Electroencephalography*. It is desirable that at least some montages in all laboratories be uniform to facilitate communication and comparison. Digital systems allow reformatting of montages to provide optimal display of activity at the time of interpretation. To permit this flexibility, initial recording must be made from a referential montage, but the system reference itself cannot easily be reformatted. For this reason, the digital recording reference should be an additional electrode (or combination of electrodes) and not one of those in the 10:10 or 10:20 system. An additional electrode between Cz and Pz is commonly used. The use of linked ears as a digital recording reference is specifically discouraged.

3.1 ^*The information associated with the record should include, as a minimum, the name and age of the patient, the date of the recording, an identification number, and the name or initials of the technologist.

Identifications should be made at the time of recording. Failure to do so may result in errors that have adverse medical and legal consequences. A Basic Data Sheet, associated with every record, should include patient name and age, the time and date of the recording, name/initials of the technologist, indication for the EEG (including description of symptoms or events, and their frequency), the time and date of the last seizure/episode (if any), the behavioral state of the patient, a list of all medications the patient has been taking (including premedication given to induce sleep during EEG), presence and location of any skull defects, and any relevant additional medical history. Any additions or modifications to standard electrode placements must be noted. Additional items that are helpful include handedness, time of last meal, and whether patient was sleep-deprived for the study. The results of previous neurophysiological testing, especially EEGs, should also be included when available.

3.2 Appropriate calibrations should be made at the beginning of every EEG recording. This includes at least 10 seconds (or the duration needed to reach a stable recording) of a square wave calibration. For analog systems, a recording with all channels connected to the same pair of electrodes should follow at the beginning (biologic calibration). At the outset, all channels should be adjusted, if necessary, so that they respond equally and correctly to the calibration signal. When doubt as to correct functioning of any amplifier exists, a repeat calibration run should be made. Biologic calibration is not necessary for digital systems.

In addition to the standard square-wave calibration, the biologic calibration may occasionally help in detecting errors in the montage selection process or in the pen-writing mechanism for analog recordings. For this purpose, an anteroposterior (frontooccipital) derivation should be used because it can include fast and alpha range patterns as well as eye movement activity in the delta range.

The calibration is an integral part of every EEG recording. It gives a scaling factor for the interpreter and tests the EEG machine for sensitivity, high-frequency and low-frequency

response, noise level, and pen alignment and damping (for analog systems). Calibration voltages must be appropriate for the sensitivities used during the recording. After calibration, visual review of a 30-second run on the system reference montage without the notch filter is also recommended.

3.3 ^*The sensitivity of the EEG equipment for routine recording should be set in the range of 5 to 10 μV/mm of trace deflection. Sensitivity is defined as the ratio of input voltage to trace deflection. It is expressed in microvolts per millimeter. A commonly used initial sensitivity is 7 μV/mm, which, for a calibration signal of 50 μV, results in a deflection of 7.1 mm. If the sensitivity is decreased (for example, from 7 to 10 μV/mm), the amplitude of the waveform visualized on the EEG also decreases. Conversely, if the sensitivity is increased (e.g., from 7 to 5 μV/mm), the amplitude of a given waveform increases on the EEG.

When the sensitivity is less than 10 μV/mm (e.g., 20 μV/mm), significant low-amplitude activity may become undetectable. If the sensitivity is greater than 5 μV/mm (e.g., 3 μV/mm), normal EEG activity may obscure the tracing and limit identification of individual waveforms and frequencies.

With digital systems, this straightforward physical relationship of sensitivity (millimeter of pen deflection for μV of input voltage) is lost. Systems can be calibrated for a specific screen, so that sensitivity retains its physical meaning. When the same data are redisplayed on a different computer monitor, however, this relationship may be lost. For this reason, clear scale markers must be shown as part of the display.

During calibration for routine recordings, the recorded signals should not be distorted but should be large enough to permit measurement to better than ±5% between any of the signals on the different channels.

No matter which sensitivity (within the above limits) is chosen before the recording, appropriate adjustments should be made whenever the EEG activity encountered is of too high or low amplitude to be recorded properly.

3.4 ^For digital recordings, filtering of the signal occurs at two levels. Analog filters are applied to the incoming signal in the actual amplifier before digitization. These are usually dependent on the specific amplifier being used and not modifiable by the user, but they do define the ultimate range of frequencies being recorded and are important to keep in mind when digitally filtering the signal after collection.

The second level of filtering consists of digital filters that are applied before display of the digitized data. These filters are analogous to the filters traditionally used in analog EEG recording, but unlike in analog recordings, the use of these filters in digital recordings does not permanently alter the recorded data; it only processes the data for display. Proper use of digital filters during data collection is still important. Improper use of digital filters may prevent the technologist from recognizing relevant EEG abnormalities, artifacts, or changes in electrode impedances that will negatively impact the quality of the recording. For standard recordings, the low-frequency filter should be no higher than 1 Hz (−3 dB), corresponding to a time constant of at least 0.16 second. The high-frequency filter should be no lower than 70 Hz (−3 dB). Note, however, that to display frequencies as high as 70 Hz, a computer monitor would need a horizontal resolution of at least 1,400 pixels in the data display area. Interpreters should be aware that some loss of high-frequency resolution will otherwise occur, along with the possibility of lower-frequency distortion because of spatial aliasing.

A low-frequency filter setting higher than 1 Hz should not be used routinely to attenuate slow-wave artifacts in the record. Vital information may be lost when pathologic activity in the delta range is present. Similarly, a setting lower than 70 Hz for the high-frequency filters can distort or attenuate spikes and other pathologic sharp features into unrecognizable forms and can cause muscle artifact to resemble spikes. Production of a record with lost or inaccurate information is poor medical practice.

It must be emphasized, however, that judicious use of the low-frequency or high-frequency filters—with appropriate annotation on the record—can emphasize or clarify certain types of patterns in the record. These filter controls, therefore, should be used selectively and carefully.

3.5 The 60-Hz (notch) filter can distort or attenuate spikes; it therefore should be used only when other measures to reduce 60 Hz interference fail.

3.6 A display of 10 to 20 seconds/page (depending on the size of the display) should be used for routine recordings (corresponding roughly to a paper speed of 30 mm/second typically used on paper EEG systems). A display of 15 to 30 seconds/page is sometimes used for EEG recordings in newborns or in other special situations.

3.7 ^The baseline record should contain at least 20 minutes of technically satisfactory recording. Longer recordings are often more informative. Although the ability to reformat a digital EEG during display allows the entire recording to be viewed in any montage after the recording, displaying the data during acquisition in only a single montage is not an acceptable practice. The EEG technologist acquiring the recording should view the EEG in at least 3 different montages (including at least one bipolar and one referential montage) during the recording to improve the ability to identify poor connections in electrodes that may not be apparent in certain montages and also to allow appreciation of subtle abnormalities that require special technical maneuvers (such as placement of additional electrodes).

The EEG is a short sample of brain activity. Within reasonable limits, a longer recording time will improve the chance of recording an abnormality or abnormalities and of demonstrating their variability. Experience in many centers shows that an absolute minimum of 20 minutes of artifact-free recording (including activation procedures) is necessary to assess baseline EEG activity. Longer recordings are more sensitive to the detection of epileptiform abnormalities and are encouraged.[6,7] The addition of photic stimulation, hyperventilation, and especially sleep (which should be recorded whenever possible) often requires an increase of recording time.

3.8 ^*The recordings should include periods when the eyes are open and when they are closed. Proper EEG recordings require examining the effect of stimuli on the EEG. A comparison between the eyes-open and eyes-closed condition constitutes one important means for assessment. Some rhythms can be masked by the alpha activity and are visible only when the alpha rhythm has been attenuated by eye-opening. Certain forms of eye movement may appear to be frontal delta or theta activity,

but eye-opening and closing helps in differentiation. Finally, paroxysmal activity may appear only when the eyes are opened or only when the eyes are closed or at the times these conditions change. Thus, failure to record with eye-opening and closing as a routine procedure can reduce chances of obtaining potentially important information. This procedure is so simple that it is unjustifiable not to request eye-opening and closure whenever patient cooperation permits or to manually open and close the eyes when it does not.

Photic stimulation should be performed in a room with dimmed lighting using a lamp placed at least 30 cm from the patient's face. Photic stimulation should be performed before hyperventilation or at least 3 minutes after hyperventilation, after all hyperventilation-related EEG changes have resolved.

Hyperventilation should be used routinely unless medical or other justifiable reasons (e.g., a recent intracranial hemorrhage, significant cardiopulmonary disease, sickle cell disease or trait, or patient inability or unwillingness to cooperate) contraindicate it. It should be performed for a minimum of 3 minutes, with continued recording for at least 1 minute after cessation of overbreathing. At times, hyperventilation must be performed for a longer period to obtain adequate activation of the EEG. To evaluate the effects of this activation technique, at least 1 minute of recording with the same montage should be obtained before overbreathing begins. The record should contain an assessment of the quality of patient effort during hyperventilation.

A single-channel electrocardiogram (ECG) should be included on one EEG channel. It is often helpful if spikes and sharp waves, or pulse or ECG artifact, are in question.

Photic stimulation and hyperventilation are provocative maneuvers intended to elicit epileptiform discharges, and potentially seizures, in susceptible patients. Patients and caregivers should be informed of this possibility in advance.

3.9 ˆ*Sleep recordings should be performed whenever possible, but not to the exclusion of the waking record. Considerable additional information can be obtained by recording during drowsiness and sleep, especially about epileptiform discharges.[8,9] Some laboratories use sleep recording routinely. Sleep recording is usually essential for patients with suspected or known seizure disorders.

Sleep deprivation may be used to increase the yield of EEGs.[10,11] In patients with epilepsy, sleep deprivation increases the frequency of detection of epileptiform discharges, even during wakefulness.

3.10ˆ*The patient's level of consciousness (awake, drowsy, sleeping, or comatose), and any change thereof, should be noted by the technologist on the EEG recording. Any commands or signals to the patient, and any movement or clinical seizure activity or absence thereof, should also be noted on the recording. Careful observation of the patient with frequent notations is often essential, particularly when unusual waveforms are observed in the tracing. Abbreviations used should be standardized, with their definitions readily available to the reader.

In stuporous or comatose patients and those showing invariant EEG patterns of any kind, visual, auditory, and somatosensory stimuli should be applied systematically during the recording. The stimuli and the patient's responses or failure to respond should be noted in the recording as near as possible to their point of occurrence.

It is the responsibility of the electroencephalographer to recognize the patterns usually associated with different states of consciousness, but observations by the technologist about the patient's clinical status can also be of considerable interpretative value, particularly when discrepancies or unusual correlations occur.

To facilitate assessing awake background activity, it is important for the technologist to ascertain that the patient is maximally alert for at least a portion of the record.

3.11 Special procedures that are of some risk to the patient should be carried out only in the presence of a qualified physician, only in an environment with adequate resuscitation equipment, and with the informed consent of the patient or responsible relative or legal guardian.

3.12 In most situations, the EEG is interpreted by a neurophysiologist after the recording is completed. This should be done in a timely fashion. The technologist should notify the interpreting physician and supervisor for critical results. These include the presence of electrographic or clinical seizures during the record, as well as other significant clinical events.

3.13 EEGs for the evaluation of cessation of cerebral function ("cerebral death") require special procedures and extraordinary precautions (see Guideline 6: *Minimum Technical Standards for EEG Recording in Suspected Cerebral Death*).

3.14 Although not an absolute requirement, simultaneous video recording with the EEG is a useful adjunct and is now routine in many laboratories. This may be useful for interpreting clinical events as well as identifying artifacts. The use of video does not reduce the importance of having an attentive technologist. If video is recorded, institutional policies should be followed regarding the need for consent. Storage and use of the video for any nonclinical purpose (e.g., educational) should also be consistent with institutional policies.

3.15 EEG data should be stored/archived in accordance with institutional and state policies for record retention. Because EEG interpretation has some subjectivity, recordings should be made available when requested by outside physicians.

DISCLAIMER

This statement is provided as an educational service of the American Clinical Neurophysiology Society (ACNS). It is based on an assessment of current scientific and clinical information. It is not intended to include all possible proper methods of care for a particular problem or all legitimate criteria for choosing to use a specific procedure. Neither is it intended to exclude any reasonable alternative methodologies. American Clinical Neurophysiology Society recognizes that specific patient care decisions are the prerogative of the patient and the physician caring for the patient based on all of the circumstances involved. The clinical context section is made available to place the evidence-based guidelines into perspective with current practice habits and challenges. Formal practice recommendations are not intended to replace clinical judgment.

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