American Clinical Neurophysiology Society

Guideline 1: Minimum Technical Requirements for Performing Clinical Electroencephalography

Introduction

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 Guideline 2: Minimum Technical Standards for Pediatric Electroencephalography).

Recording at minimum standards should not give pride to the EEG department working at this level and cannot ensure a satisfactory test. Minimum standards provide barely adequate fulfillment of responsibilities to the patient and the referring physician.

To the minimum standards have been added recommendations to improve standardization of procedures and also facilitate interchange of recordings and assessment among laboratories in North America. More detail is provided in recommendations from the International Federation of Clinical Neurophysiology (Deuschl and Eisen, 1999).

1. Equipment

1.1 To find 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 simultaneously, the chances of interpretive errors increase, and, conversely, when more channels are utilized, the likelihood of such errors decreases. This is particularly true for transient activity.

Sixteen channels of simultaneous recording are now 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.

1.2 Alternating current (AC) wiring should meet the Underwriters Laboratories standards required for hospital service. Adequate grounding of the instrument must be provided by all AC receptacles. All equipment in each patient area in the EEG laboratory must be grounded to a common point.

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 equipment should conform with the recommendations in Guideline 8.

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 effectively used especially with contemporary amplifiers having high input impedances. High-quality electrodes are available from several manufacturers and are generally preferable to homemade electrodes.

To decrease noise, electrodes must be kept clean, with appropriate precautions taken after recording from patients with contagious diseases (viral hepatitis, Creutzfeldt-Jakob disease, acquired immunodeficiency syndrome.) (AEEGS, 1994; ASET, 2000)

2.2 Needle electrodes are not recommended. If circumstances necessitate their use, they must be completely sterilized or discarded after use, and the technologist who employs them should have been taught the exact techniques, as well as the disadvantages and hazards, of their use. Parallel anteroposterior alignment of the needles is important; misalignment may cause artifactual amplitude asymmetries or distortions.

It is rarely appreciated that proper use of needle electrodes requires more care and expertise than for any other type of electrode. However, needle electrodes can be effectively utilized in comatose patients, in whom pain responses are usually minimal or absent, and who are in medical settings requiring efficient recording with a minimum of delay.

2.3 All 21 electrodes and placements recommended by the International Federation of Clinical Neurophysiology (IFCN; Jasper HH, 1958, 1983) should be used. The 10-20 System is the only one officially recommended by the IFCN. It is the most commonly used existing system, and it should be used universally. The use of the term "modified 10-20 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 10-20 placement" is more appropriate. The term "10-10 System" should be used for the extended combinatorial system described in Guideline 5. (For neonates, refer to Guideline 2.)

An adequate number of electrodes is 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 in order to record very localized activity.

A grounding electrode always should be used, except in situations (e.g., intensive care units, operating rooms) in which other electrical equipment is attached to the patient. In such cases, double grounding must be avoided. The ground electrode on the patient must be connected only to the appropriate jack of the input jackbox, and never to the equipment chassis or other earth ground.

2.4 Interelectrode impedances should be checked as a routine prerecording procedure. Ordinarily, electrode impedance should not exceed 5000 Ohms (5 KOhms.)

Electrode impedances should be rechecked during the recording when any pattern that might be artifactual appears.

3. Recordings

3.1 Montages should be designed in conformity with Guideline 6: 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.

3.2 The record should have written on it 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, attached to every record, should include the time of the recording, the time and date of the last seizure (if any), the behavioral state of the patient, a list of all medications that the patient has been taking, including premedication given to induce sleep during EEG, and any relevant additional medical history.

3.3 Appropriate calibrations should be made at the beginning and end of every EEG recording. If feasible, a recording with all channels connected to the same pair of electrodes should follow at the beginning. However, this biological calibration may not be possible with all digital systems. 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.

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 and low-frequency response, noise level, and pen alignment and damping. It also gives information about the competence and care of the technologist. Calibration voltages must be appropriate for the sensitivities used.

In addition to the standard square-wave calibration, the biologic calibration ("bio-cal") may at times be of additional help in detecting errors in the montage selection process or in the pen-writing mechanism. For this purpose, an anteroposterior (frontooccipital) derivation should be used, since it can include fast and alpha range patterns as well as eye movement activity in the delta range. In digital systems that lack full provision for instrumental and biological calibration, the first 30 seconds of recording should be observed by the technologist from the primary system-reference montage.

3.4 The sensitivity of the EEG equipment for routine recording should be set in the range of 5—10 uV/ mm of pen deflection.

Sensitivity is defined as the ratio of input voltage to pen deflection. It is expressed in microvolts per millimeter (uV/mm). A commonly used sensitivity is 7 uV/mm, which, for a calibration signal of 50 uV, results in a deflection of 7.1 mm.

If the sensitivity is decreased (for example, from 7 to 10 uV/mm), the amplitude of the writeout of a given EEG on the paper also decreases. Conversely, if the sensitivity is increased (for example, from 7 to *5* uV/ mm), the amplitude of the writeout of a given EEG increases.

When the sensitivity is less than 10 uV/mm (for example, 20 uV/mm), significant low-amplitude activity may become indiscernible. If the sensitivity is greater than *5* uV/mm (for example, 3 uV/mm), normal EEG activity may overload the system, causing a squaring off of the peaks of the writeout onto the paper or overlapping of traces on the computer monitor.

Note that a sensitivity of 5 uV/mm means that, to obtain a pen deflection of 1 mm, a 5-uV input voltage is required (and correspondingly, to obtain a 10-mm deflection, an input of 50 uV is required). If the sensitivity is decreased to 10 uV/mm, the same 1-mm pen deflection now requires a larger input, i.e., 10 uV rather than *5* uV (and correspondingly, a 10-mm pen deflection now requires an input of 100 uV rather than 50 uV). Thus, as the sensitivity is increased, its numerical value becomes smaller. Conversely, as the sensitivity is decreased, its numerical value becomes larger. This perhaps seemingly paradoxical relationship is actually a logical consequence of the definition of sensitivity as input voltage per unit of pen deflection.

With digital systems, this straightforward physical relationship is lost. Because the dimensions of computer monitors will vary, clear scale markers must be available as part of the display.

The operation of EEG amplifiers can also be expressed as gain, defined as the ratio of the output voltage to the input voltage. For example, if an EEG input signal of 10 uV is amplified to 1.0 V in order to move the mechanical pens of an electroencephalograph, then the gain is 1.0/.00001 = 100,000. The gain of an analog or digital system is not as obvious to the user as the sensitivity.

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 prior to the recording, appropriate adjustments should be made whenever EEG activity encountered is of too high or low amplitude to be recorded properly.

3.5 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 s. 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 1400 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 due to 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 discharges 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- 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.

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

3.7 A paper speed of 3 cm/s, or digital display of 10 seconds/page, should be utilized for routine recordings. A paper speed of 1.5 cm/s, or 20 seconds/page, is sometimes used for EEG recordings in newborns or in other special situations.

3.8 When instrument settings (sensitivities, filters, paper speed, montage) are changed during the recording, the settings should be clearly identified on the record at the time of the change. If technologically feasible, the final calibration(s) should include each sensitivity and filter settings used in the recording, and should include calibration voltages appropriate to the sensitivities actually used. It is especially important to record calibration signals at very high sensitivities when these settings have been used. With some digital systems, a gain factor display may be the only available assessment for function of the analog system. More comprehensive calibrations, such as those described above, are encouraged.

3.9 The baseline record should contain at least 20 min of technically satisfactory recording. Longer recordings are often more informative. Although the possibility of reformatting digital EEG allows the entire recording to be performed in a single montage, this is not acceptable practice. Observing only one montage may prevent recognition of poor connections in

electrodes that happen not to be included, and also prevent appreciation of subtle abnormalities that require special technical maneuvers (such as placement of additional electrodes.)

The EEG is a short sample in time from the patient's life. Within reasonable limits, the longer the recording, the better the chance of recording an abnormality or abnormalities demonstrating the variability of these. Experience in many centers shows that a very minimum of 20 min of artifact-free recording is necessary to assess baseline waking EEG activity. The addition of photic stimulation, hyperventilation, and especially sleep—which should be recorded whenever possible—often requires an increase of recording time.

3.10 The recordings should include periods when the eyes are open and when they are closed.

Proper EEG recordings requires examining the effect of stimuli upon 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.

3.11 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 min with continued recording for at least 1 min after cessation of overbreathing. At times, hyperventilation must be performed for a longer period in order to obtain adequate activation of the EEG. To evaluate the effects of this activation technique, at least 1 min 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. It is often helpful to record electrocardiographic (ECG) activity directly on one EEG channel during this and other parts of the recording, particularly if spikes and sharp waves, or pulse or ECG artifact, are in question. With an additional (e.g., 17th) channel, the ECG can be monitored continuously.

3.12 Sleep recordings should be taken whenever possible but not to the exclusion of the waking record.

It is increasingly evident that considerable additional information can be obtained by recording during drowsiness and sleep. Some laboratories use sleep recording routinely. Sleep recording is usually essential for patients with suspected or known convulsive disorders.

3.13 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 recording. The stimuli and the patient's responses or failure to respond should be noted on the recording paper as near as possible to their point of the occurrence.

It is the responsibility of the electroencephalographer to recognize the patterns usually associated with different states of consciousness. However, observations by the technologist about the patient's clinical status can 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.

3.14 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 resuscitating equipment, and with the informed consent of the patient or responsible relative or legal guardian.

3.15 EEGs for the evaluation of cessation of cerebral function ("cerebral death") require special procedures and extraordinary precautions (see Guideline 3: Minimum Technical Standards for EEG Recording in Suspected Cerebral Death).

REFERENCES

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