

## American Clinical Neurophysiology Society

### Guideline 3: Minimum Technical Standards for EEG Recording in Suspected Cerebral Death

#### Introduction

EEG studies for the determination of cerebral death are no longer confined to major laboratories. Many small hospitals have intensive care units and EEG facilities. The need for minimal standard guidelines has thus increased.

The first (1970) edition of Minimum Technical Requirements for EEG Recording in Suspected Cerebral Death reflected the state of the art and the technique of the late 1960s. Substantially improved EEG instrumentation is now available, and many laboratories have had years of experience in this area. Equally important, there is now a much larger number of competent EEG technologists. Finally, the EEG results of a collaborative study of cerebral death that was being planned in 1970 have been published (Bennett et al., 1976).

The survey in the later 1960s by the American EEG Society's Ad Hoc Committee on EEG Criteria for the Determination of Cerebral Death revealed that, of 2,650 cases of coma with presumably "isoelectric" EEGs, only three whose records satisfied the committee's criteria showed any recovery of cerebral function. These three had suffered from massive overdoses of nervous system depressants, two from barbiturates, and one from meprobamate. Many of the reported "isoelectric" records were, on review, either low-voltage records or obtained with techniques inadequate to bring out low-voltage activity. That is, inadequate technique alone gave the graphs the appearance of being "flat." It should be pointed out, however, that this study did not include children. Hence, the comparable data on which to base recommendations for this young age group do not exist at present. The 1970 committee recommended dropping nonphysiologic terms such as "isoelectric" or "linear" (the word "flat" should likewise not be used) and renaming the state "electrocerebral silence." Subsequently, "electrocerebral inactivity" (ECI) was the term recommended in the Glossary of the International Federation of Clinical Neurophysiology (IFCN; Chatrian et al., 1974).

The current Guideline includes an updating of the criteria for electrocerebral inactivity, reflecting what has been learned since the first appearance of these standards (Chatrian et al., 1974; Bennett et al., 1976; Chatrian, 1980; NINCDS, 1980; Medical Consultants, 1981; Walker, 1981).

#### Definition

Electrocerebral inactivity (ECI) or electrocerebral silence (ECS) is defined as no EEG activity over 2  $\mu$ V when recording from scalp electrode pairs 10 or more cm apart with interelectrode impedances under 10,000 Ohms (10 KOhms), but over 100 Ohms.

Ten guidelines for EEG recordings in cases of suspected cerebral death, with the rationale for each, are set forth with explanatory comments.

#### 1. A Full Set of Scalp Electrodes Should Be Utilized

The major brain area must be covered to be certain that absence of activity is not a focal phenomenon. The use of a single-channel instrument such as is sometimes used for EEG monitoring of anesthetic levels is therefore unacceptable for the purpose of determining ECI. The frontal, central, occipital, and temporal areas are recommended as the minimal required coverage. A grounding electrode should be added. However, for recordings in intensive care units, a ground electrode should *not* be used if grounding from other electrical equipment is already attached to the patient.

Since, prior to the recording, one does not know whether an ECI record will be obtained, it is desirable to use a full set of scalp electrodes on the initial examination, as defined in Guideline One: Minimum Technical Requirements for Performing Clinical Electroencephalography, Section 2.3. At times, the full set of conventional 10-20 scalp locations may not be accessible because of head trauma or recent surgery. Otherwise, the initial study should not use less than the routine coverage standard for the particular clinical laboratory. A full set of electrodes includes midline placements (Fz, Cz, Pz); these are useful for the detection of residual low-voltage physiologic activity and are relatively free from artifact. Since the EEGs of patients with suspected ECI actually may have EEG abnormalities other than ECI, the use of more complete, rather than less complete, electrode coverage is often essential.

## **2. Interelectrode Impedances Should Be Under 10,000 Ohms But Over 100 Ohms**

**2.1** Unmatched electrode impedances may distort the EEG. When one electrode has a relatively high impedance compared to the second electrode of the pair, the amplifier becomes unbalanced and is prone to amplify extraneous signals unduly. This may result in the occurrence of 60-Hz interference or other artifacts. Situations characterized by low-voltage electrocerebral activity and high instrument sensitivity demand especially scrupulous electrode application.

**2.2** There is a marked dropoff of potentials with impedances below 100 Ohms and, of course, no potential at 0 Ohms. Such an occurrence could be one possible reason for a false ECI record. A test of inter-electrode impedances to assure that they are of adequate magnitude thus should be performed during the recording. When fixed arrays of electrodes ("electrode cap" or similar devices) are utilized, it is essential that excess jelly does not spread from one electrode to another, creating a shunt or short circuit, which would attenuate the signal.

Stable, low-impedance electrodes are absolutely essential for all bedside (i.e., away from the laboratory) studies.

**2.3** Although not recommended for general use, needle electrodes have been used effectively in suspected ECI recordings. The greater impedance they may have is offset by a greater probability of similar values among different electrodes, so that the likelihood that artifact will occur in the record is not increased. (See also Guideline 1: Minimum Technical Requirements for Performing Clinical Electroencephalography, Section 2.2.)

## **3. The Integrity of the Entire Recording System Should Be Tested**

Ordinary instrumental calibration tests the operation of the amplifiers and writer units, but it does not exclude the possibility of shunting or an open circuit at the electrodes, electrode board (jackbox), cable, or input of the machine. If, after recording on one montage at increased amplification, an EEG suggesting ECI is found, the integrity of the system may be tested by touching each electrode of the montage gently with a pencil point or cotton swab to create an

artifact potential on the record. This test verifies that the electrode board is connected to the machine; records made with the electrode board inadvertently not connected can sometimes resemble low-amplitude EEG activity. The test further proves that the montage settings match the electrode placements.

#### **4. Interelectrode Distances Should Be at Least 10 Centimeters**

In the International 10-20 System, the average adult interelectrode distances are between 6 and 6.5 cm. A record taken with average interelectrode distances at ordinary sensitivity may suggest ECI; however, if it were recorded using longer interelectrode distances, cerebral potentials might be seen in the tracing. Hence, with longitudinal or transverse bipolar montages, some double distance electrode linkages are recommended (e.g., Fp1-C3, F3-P3, C3-O1, etc.).

Ear reference recording is almost invariably too contaminated by EKG to be useful but a Cz reference may be satisfactory. In one study (Bennett et al., 1976), the best montage was: Fp2-C4, C4-O2, Fp1-C3, C3-O1, T8 (T4)-Cz, Cz-T7 (T3), with one-channel EKG and one-channel noncephalic (hand). Occipital leads, however, are more difficult to attach in immobilized patients and are particularly susceptible to movement artifact induced by artificial respirators. A montage that includes F7-P7 (T5), F8-P8 (T6), F3-P3, F4-P4, and Fz-Pz may therefore yield a better record.

None of the foregoing should imply that the usual preselected laboratory montages could not also be used.

#### **5. Sensitivity Must Be Increased from 7 uV/mm to at Least 2 uV/mm for at Least 30 Minutes of the Recording, with Inclusion of Appropriate Calibrations**

**5.1** This is undoubtedly the most important and the most often overlooked parameter. One has only to realize that at a sensitivity of 7 uV/mm a signal of 2 uV cannot be seen because the average ink line is 1/4 mm in width, i.e., about the size of the signal one desires to see. Obviously, the criterion voltage of 2 uV will deflect the pen only 1 mm at a sensitivity of 2 uV/mm. Such a signal should be visible at 2 uV/mm, and more certainly so at a sensitivity of 1.5 or 1 uV/mm. On most computer monitors, a single pixel is about 1/3 mm high, so that the effective sensitivity should be slightly higher; e.g., a 2 uV signal should move the signal trace at least 1.5 mm on the screen. However, very slow activity with gradual wave slopes still may be difficult to see. Contemporary equipment permits extended recording at a sensitivity of 1.5 or 1 uV/mm. This 50—100% increase in sensitivity will allow a more confident assessment of the presence, or the absence, of a 2-uV signal.

**5.2** Adequate and appropriate calibration procedures are essential. It is good practice to calibrate with a signal near the size or value of the EEG signal that has been recorded; thus, for electrocerebral inactivity, a calibration of 2 or 5 uV is appropriate. A 50-uV calibration signal at a sensitivity of 2 or 1 uV/mm is useless, since the pens block and monitor traces may overlap. The inherent noise level of the recording system also should be noted.

**5.3** Self-limited periods of ECI of up to 20 min may occur in low-voltage records (Jorgensen, 1974), and, therefore, a single recording should be at least 30 min long to be certain that intermittent low-voltage cerebral activity is not missed.

#### **6. Filter Settings Should Be Appropriate for the Assessment of ECS**

In order to avoid attenuation of low-voltage fast or slow activity, whenever possible, high-frequency filters should not be set below a high-frequency setting of 30 Hz, and low-frequency filters should not be set above a low-frequency setting of 1 Hz.

It is well-known that short time constants (high values of the low filter) attenuate slow potentials. In the situation approaching ECI, there may be potentials in the theta and delta ranges, so every effort should be made to avoid attenuation of these low frequencies. However, it has been demonstrated that a low-frequency setting of 1 Hz is adequate for the determination of ECI (Jorgensen, 1974; Bennett et al., 1976). There need be no hesitation in the use of the 60-Hz notch filter.

## **7. Additional Monitoring Techniques Should be Employed When Necessary**

The EEG record is a composite of true brain waves, other physiologic signals, and artifacts (either internal or external to the machine, and of mechanical, electromagnetic, and/or electrostatic origin). When the sensitivity is increased, such artifacts are accentuated and therefore must be identified in order to accurately assess whether EEG is present. It should be emphasized that the best insurance against many artifacts is a stable, low-impedance electrode system. A wide range of artifacts is illustrated in the *Atlas of Electroencephalography in Coma and Cerebral Death* (Bennett et al., 1976) and in *Current Practice Of Clinical Electroencephalography* (Chatrian et al., 2003.) Because the Atlas is now difficult to obtain, Raven Press has kindly granted permission to use some of the figures, which are found below.

**7.1** Since one rarely sees an ECI record without varying amounts of EKG artifact, an EKG monitor is essential.

**7.2** If respiration artifact cannot be eliminated, the artifact must be documented by specific technologist notation on the record or be monitored by transducer. Briefly disconnecting the respirator will allow definitive identification of the artifact.

**7.3** Frequently, an additional monitor is needed for other artifact emanating from the patient or for artifact induced from the surroundings. The most convenient for this purpose is a pair of electrodes on the dorsum of the hand separated by about 6-7 cm.

**7.4** It is now clear that some EMG contamination can persist in patients with ECI recordings. If EMG potentials are of such amplitude as to obscure the tracing, it may be necessary to reduce or eliminate them by use of a neuromuscular blocking agent such as pancuronium bromide (Pavulon) or succinylcholine (Anectine). This procedure should be performed under the direction of an anesthesiologist or other physician familiar with the use of the drug.

**7.5** Machine noise and external interference may be conveniently checked by a “dummy patient,” i.e., a 10,000-Ohm resistor between input terminal 1 (G1) and input terminal 2 (G2) of one channel.

**7.6** Even with good technique, however, an EEG recorded at the increased sensitivities required above can at times leave the electroencephalographer who interprets the recordings in considerable difficulty. An attempt must be made to determine what portion of the record results from noncerebral physiologic signals, or nonphysiologic artifacts, including the ongoing noise level of the complete system in the particular ICU as indicated, for example, by a recording from the hand. An estimate must then be made of whether or not the remaining activity exceeds 2  $\mu$ V

in amplitude. When this cannot be done with confidence, the EEG report must indicate the uncertainty, and the record cannot be classified as demonstrating ECI (see Section 10).

## **8. There Should Be No EEG Reactivity to Intense Somatosensory, Auditory, or Visual Stimuli**

In the collaborative study, there was no instance of stimulus-related activity in routine recordings of patients with ECI (Bennett et al., 1976; NINCDS, 1980; Walker, 1981). Any apparent EEG activity resulting from the above stimuli or any others (airway suctioning and other nursing procedures can be potent stimuli) must be carefully distinguished from noncerebral physiologic signals and from nonphysiologic artifacts. For example, an electroretinogram can still persist in response to photic stimulation when there is ECI. Stimulation may be of help also in documenting the degree of reactivity of records found not to be characterized by ECI.

## **9. Recordings Should Be Made Only by a Qualified Technologist**

Great skill is essential in recording cases of suspected ECI. The recordings are frequently made under difficult circumstances and include many possible sources for artifact. Elimination of most artifact and identification of all others can be accomplished by a qualified technologist.

Qualifications for a competent EEG technologist for ECI recordings include the requirement of supervised instruction in the techniques of recording in ICU settings. Additionally, Registry in EEG Technology (R. EEG T.) is encouraged for technologists performing such studies. The technologist should work under the direction of a qualified electroencephalographer.

## **10. A Repeat EEG Should Be Performed If There is Doubt About ECI**

In the Collaborative Study of Cerebral Death (Bennett et al., 1976; NINCDS, 1980; Walker, 1981), there were no patients who survived for more than a short period after an EEG showed ECI, provided that overdose of depressant drugs was excluded. This finding confirmed the results of the earlier survey, which were summarized in the Introduction. It is evident, therefore, that a single EEG showing ECI is a highly reliable procedure for the determination of cortical death. (For other guidelines to assist physicians in the determination of brain death, see the References.)

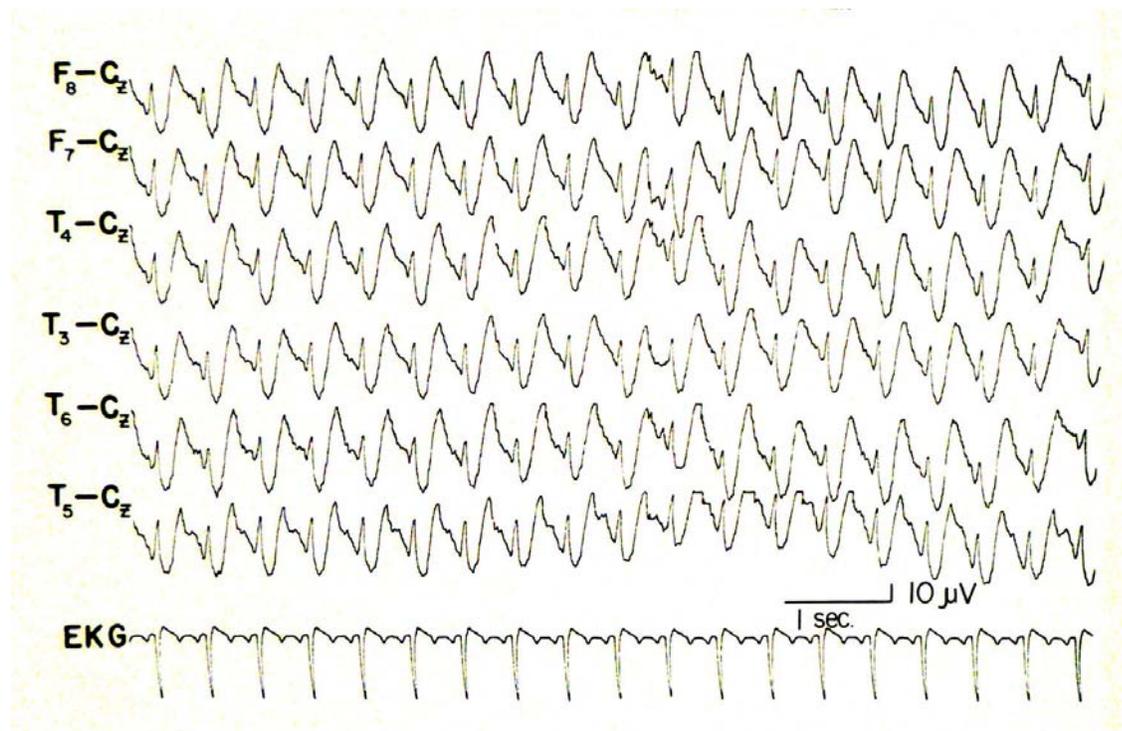
In the event that technical or other difficulties lead to uncertainty in the evaluation of the question of ECI, the entire procedure should be repeated after an interval, for example, after 6 h (see Section 7).

## **REFERENCES**

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7. The NINCDS Collaborative Study of Brain Death. NINCDS Monograph No. 24, NIH Publication No. 81-2286, December 1980.
8. Walker AE. *Cerebral death*. Baltimore: Urban & Schwarzenberg, 1981.

### FIGURES



**Figure 1. Very spiky appearing EKG artifact.** Sensitivity 2 uV/mm. Reproduced with permission from Bennett, D.R., et al, Atlas of Electroencephalography in Coma and Cerebral Death, Raven Press, New York, 1976.

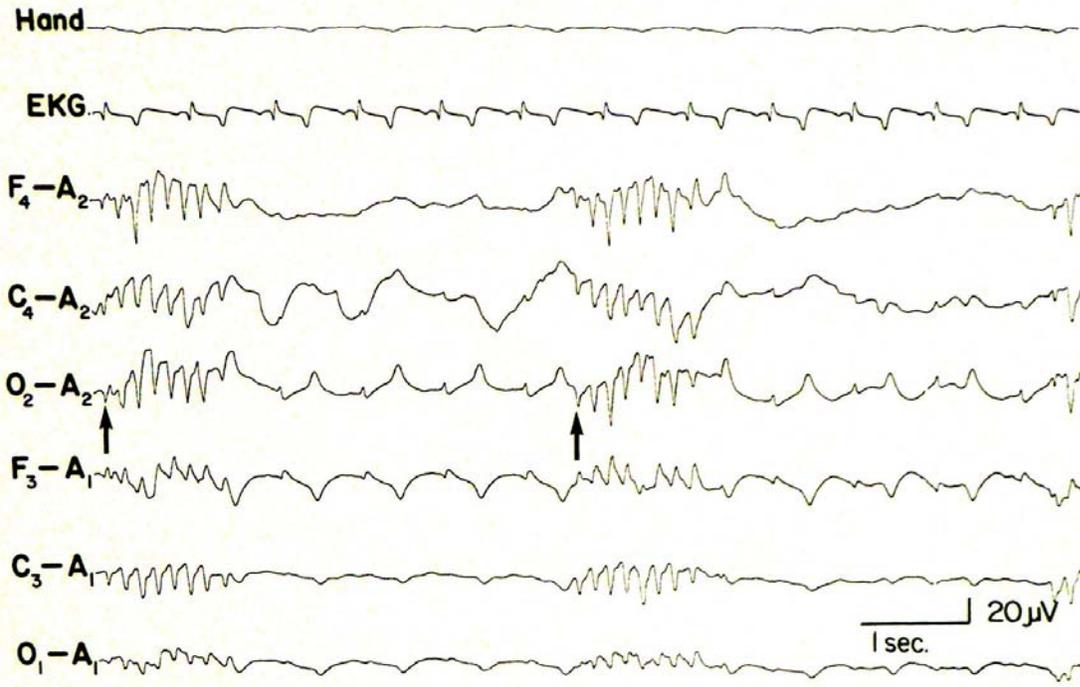


Figure 2. Clusters of respirator artifact mimicking theta-frequency burst suppression (arrows at onset.) Note also, in O<sub>2</sub> - A<sub>2</sub> and F<sub>3</sub> - A<sub>1</sub>, the presence of pulse artifact resembling rhythmic delta. Sensitivity 5 uV/mm. Reproduced with permission from Bennett, D.R., et al, Atlas of Electroencephalography in Coma and Cerebral Death, Raven Press, New York, 1976.

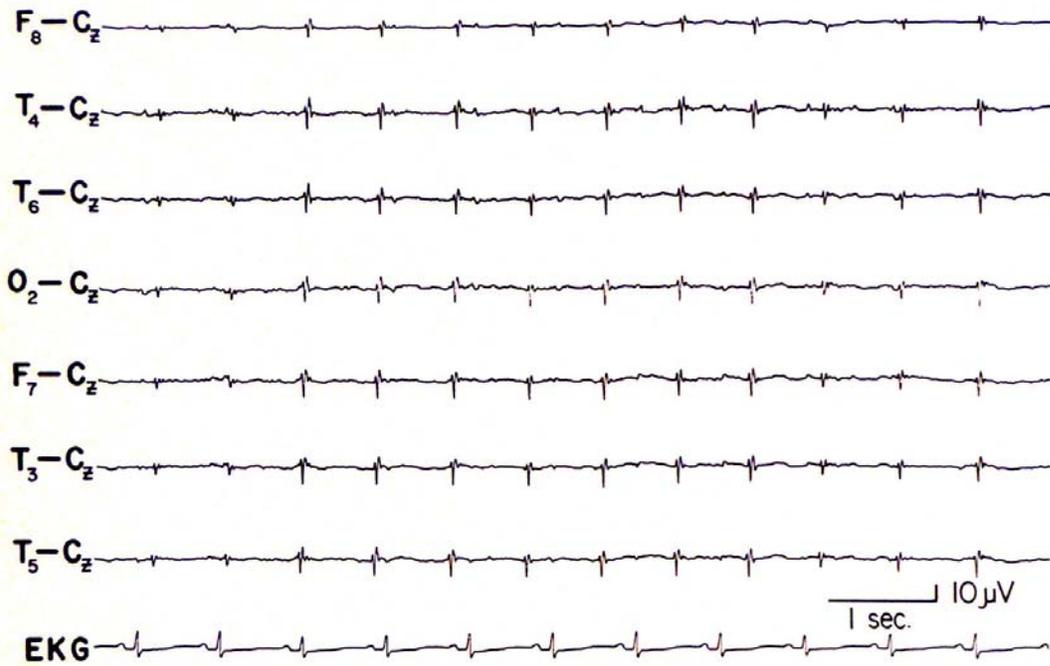
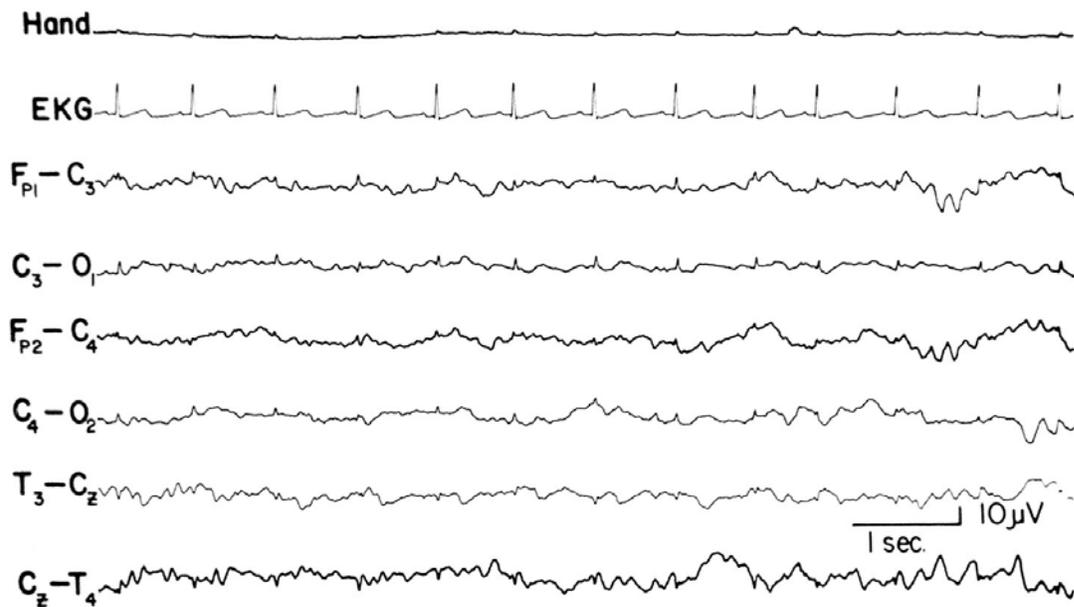


Figure 3. Intravenous drip artifact, occurring independent of EKG and resembling periodic spikes. Sensitivity 2 uV/mm. Reproduced with permission from Bennett, D.R., et al, Atlas of Electroencephalography in Coma and Cerebral Death, Raven Press, New York, 1976.



**Figure 4. Low-voltage, mixed-frequency alpha, theta, and delta at sensitivity 2 uV/mm.** Reproduced with permission from Bennett, D.R., et al, Atlas of Electroencephalography in Coma and Cerebral Death, Raven Press, New York, 1976.