

## American Clinical Neurophysiology Society

### Guideline 4: Recording Clinical EEG on Digital Media

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#### Introduction

Digital EEG recording systems are now widely available and relatively inexpensive. They offer multiple advantages over previous analogue/paper systems, such as higher fidelity recording, signal post-processing, automated detection, and efficient data storage. Unlike previous analogue EEG recordings, digital EEG acquisition allows the reviewer to view the EEG record with control over the montage, filter settings, gain, and horizontal scaling (seconds of EEG recording viewed per screen page). In hospitals that offer continuous monitoring, digital video-EEG recordings can be streamed directly to a central server for secure storage and review at remote sites.

#### 1. Patient Information

The electronically recorded information should include the patient's name and date of birth, date on which the test was run, and relevant patient and laboratory identification numbers. Preferably, the EEG report will be stored and merged with the EEG signal after review of the record by a physician. Correction of errors or omissions in the patient-identifying information should also be possible after the recording.

#### 2. Notation of Information during the EEG Recording

Calibration signals should be recorded at the beginning of each recording, in the manner already conventional for EEG (See Guideline 1, section 3.2). The time of day should be recorded along with the EEG data, as well as any other information that could be used for finding events in the stored record. The recording itself should contain all of the technologist's comments. The technologist should be able to enter event codes and comments even after the EEG recording has been completed. Codes recorded with the data can represent common events such as eyes closure or eye opening; the beginning and end of hyperventilation; details of photic stimulation; and notation of the patient's alert, drowsy, or asleep state. It should also be possible to enter free text comments which are then stored along with the EEG data. In addition, there should be provisions for automatically recording information such as impedance values, sampling frequency, filter settings, gain, montage selections, and other technical amplifier control settings at the start of the recording. Any changes made during the recording should be recorded immediately with the EEG data.

#### 3. Recording

Acquisition of EEG data onto a digital storage medium should occur at a minimum sampling rate of 256 samples per second. This is selected to be more than three times the high-

frequency filter setting, assuming a typical 70-Hz high filter setting. Higher rates, such as 512 Hz, are preferable to prevent aliasing on modern high-resolution computer screens. Also, because automated detection algorithms are becoming a standard feature of many EEG acquisition systems, higher sampling rates are preferred. Digitization should use a resolution of at least 16 bits per sample including any sign bit. Most modern clinical EEG amplifiers record with a bit depth of 24. A resolution of 16 or more bits is preferable; this allows for an EEG resolution down to 0.05  $\mu\text{V}$  while recording potentials up to plus-or-minus several millivolts without clipping. For example, with a 0.05- $\mu\text{V}$  resolution and a 16-bit analog-to-digital conversion, the maximum allowed excursion would be  $\pm 1.638 \text{ mV}$ . This is the dynamic range of the system. Interchannel crosstalk should be less than 1%, i.e., 40 dB down or better. Common mode rejection ratio should be at least 90 dB (and preferably higher) for each of the channels. Additional noise in the recording should be less than 1  $\mu\text{V}$  peak-to-peak at any frequency 0.5-100 Hz, including at 60 Hz. Ideally, video recording should be synchronized with the EEG to facilitate review, especially for identification of artifacts and clinical events.

#### **4. Recording Storage**

Currently, nonerasable and erasable optical storage devices are acceptable for the storage of outpatient routine, one hour, six-hour video-EEG, and ambulatory EEG recordings. For optical storage, digital EEG systems should employ widely-supported types of storage media (e.g. CD-ROM, DVD-ROM, or Blue Ray BD-R or BD-RE), but optical storage devices are not recommended. This is not only because optical discs can be easily damaged, but also because the optical disc medium is likely to disappear over the next few years. As with floppy disc recordings of the 1990s, newer computers will probably lose the ability to read optical discs in the near future, making it difficult to view these EEG recordings. Newer storage technologies such as USB flash drives and network access servers are inexpensive, more reliable, and practical for even a small Neurology practice. For inpatient long-term recordings lasting 24 hours or more, storage on a digital server system is recommended; this can facilitate review in remote locations and backup by hospital IT staff. Storage of video-EEG data on business grade server storage solutions minimizes the chance of data loss by incorporating built-in data storage redundancy and regular data back-up.

EEG recording formats should be able to store not only the EEG signal data but also the technologist's comments and event codes (for evoked potentials and other events). For research purposes, manufacturers should provide a method for outputting copies of the recording with patient identifiers removed. EEG recording systems should be able to input and output nonproprietary publicly available data formats (such as EDF or EDF-plus) for storage of EEG data, so that other manufacturers or third party software vendors can read the EEG record or translate it into a format readable by another manufacturer's equipment. Manufacturers should provide a method for outputting studies in their format with a stand-alone viewer so that the recording can be viewed by a user on any computer.

Manufacturers should also guarantee that newer reader systems can still read older data recorded by the equipment of that manufacturer, even when those data are no longer compatible with current reading systems. This could be accomplished if manufacturers provide a service to their customers to convert all of their older media and files to the

current format, and if EEG laboratories remain aware of deteriorating legibility or technical obsolescence of older recordings and ensure that they are converted when necessary. Manufacturers should also inform customers in a timely fashion of the need to convert their data files to maintain legibility. We recognize uncertainty regarding the availability of commercial digital EEG review devices to replay the stored EEG years into the future, given changes in EEG recording formats. The present lack of a format standard for digital video-EEG recording frequently results in incompatibility between various commercially available devices and may lead to the impossibility of reading and repair of past EEG recordings. Note is made of the existence of statutes governing medical records in each of the individual states, as well as existence of local or hospital statutes regarding EEG record storage. These govern the duration of storage, and in some instances they may also dictate whether magnetic or optical storage is allowed.

## 5. Display

A recording system for clinical use should have the capability to review recorded EEG data on the computer screen with sufficient temporal and spatial resolution. A standard horizontal scaling should be available in which 1 second occupies between 25 and 35 mm, with a minimum resolution of 128 data points/second on the screen for a ten second page, requiring a horizontal resolution of at least 1280 pixels. Other more compressed and more expanded horizontal scales should also be available, including scaling differing from standard by a factor of 2, e.g., 7.5, 15, 30, or 60 mm/sec. Vertically, appropriate channel spacing between the baseline of each channel depends on the number of channels displayed. A standard vertical scaling with a minimum spacing of 10 mm per channel should be used for a display of up to 21 channels. Other choices for vertical scaling may be provided as well. Larger gaps can be introduced where necessary to separate blocks of channels and increase readability. Occasional overlap of data between channels is acceptable. The horizontal and vertical scales on the screen should be indicated on the display. For purposes of comparison between different devices, important considerations are the maximum number of channels and the maximum number of seconds that can be displayed on a single screen, using the standard scaling as defined above. *Post hoc* digital filtering should also be available. Control of filter settings should be provided for each individual channel. The system should allow simultaneous display of multiple segments of EEG, allowing side-by-side visual comparison of different segments within one recording as well as different segments from different recordings obtained on different days. Although many digital EEG review systems may display results of EEG processing such as trending or automated detections, the reviewer should always be given easy access to view the raw EEG data.

Montages available for review should be consistent with those in standard use in the laboratory and with ACNS recommendations (see Guideline 3), preferably allowing additional user flexibility. This should be done using bipolar and referential reconstruction techniques. Playback systems should be able to display channel (montage) designations, gain or filter settings where appropriate, technologist comments, and event markers, along with the raw or transformed EEG data. A time stamp on each screen or page of EEG data is essential.

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