GUIDELINE

American Clinical Neurophysiology Society Guideline 5: Minimum Technical Standards for Pediatric Electroencephalography

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Summary: This revision to the EEG Guidelines is an update incorporating the current electroencephalography technology and practice. It was previously published as Guideline 2. Similar to the prior guideline, it delineates the aspects of Guideline 1 that should be modified for neonates and young children. Recording conditions for photic stimulation and hyperventilation are revised to enhance the provocation of epileptiform discharges. Revisions recognize the difficulties involved in performing an EEG under sedation in young children. Recommended neonatal EEG montages are displayed for the reduced set of electrodes only since the montages in Guideline 3 should be used for a 21-electrode 10-20 system array. Neonatal documentation is updated to use current American Academy of Pediatrics term "postmenstrual age" rather than "conceptional age." Finally, because therapeutic hypothermia alters the prognostic value of neonatal EEG, the necessity of documenting the patient's temperature at the time of recording is emphasized.

Key Words: Electroencephalography, EEG, Guideline, Technical, Neonate, Children, Pediatric, Hyperventilation, Photic Stimulation, Montage, Electrode, Filter, Postmenstrual Age, Conceptional Age, Therapeutic Hypothermia.

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These Guidelines for clinical EEG recording in children should be considered in conjunction with the more general ACNS Guideline 1: *Minimum Technical Requirements for Performing Clinical Electroencephalography* (MTR), which covers primarily EEG recording in adults.

The basic principles of clinical EEG outlined in Guideline 1 also apply to the very young and are reaffirmed here. Special considerations pertinent to pediatric recordings are discussed below, with emphasis on the EEG in neonates, infants, and young children. EEG recording in older children and adolescents differs little from recording the EEGs of adults. Because EEG recording in the newborn presents a number of special problems; this Guideline is divided into two parts, setting forth recommendations for children and for neonates separately. [Notation in brackets in this Guideline refers specifically to sections of Guideline 1 which must be modified for pediatric recordings. For situations not covered here, the recommendations of Guideline 1 remain appropriate and should be consulted.]

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1. CHILDREN

1.1 [MTR 2.1]

Because children, especially young children, have a tendency to move a good deal during EEG recordings, electrode application should be performed with great care. Electrodes may be applied with paste or collodion, according to the preference of the laboratory, but their positions and impedances should be monitored carefully throughout the study. Needle electrodes should not be used.

1.2 [MTR 2.3]

All 21 electrodes of the International 10-20 system[1] should be used for most purposes. The standard montages used for adults should be used for children.

1.3 [MTR 2.4, 3.2]

Recommendations of MTR 2.4 and 3.2 should be followed. Particularly active children may require more frequent review of electrode recording quality during the recording.

1.4 [MTR 3.1]

Before recording the EEGs of young inpatients, especially those in so precarious a condition that the recordings must be

done at the bedside, the technologist should consult with the nursing staff concerning the patient's condition and about any necessary limitations on recording procedures.

1.5 [MTR 3.3]

The voltage of EEG activity in many young children is higher than that of older children and adults, and appropriate reduction of sensitivity (to 10 μV/mm, or even 15 μV/mm) could be used as needed. At least a portion of the record should be run at a sensitivity (such as 7 μV/mm) adequate to display low-voltage fast activity. Otherwise, for patients beyond infancy, the same instrument control settings can be used as for adults in the same laboratory.

1.6 [MTR 3.8]

It is advised to perform hyperventilation at the beginning and photic stimulation at the end of the recording to maximize spontaneous sleep.[2] If hyperventilation fails to elicit diagnostic findings in patients with suspected absence or other primary generalized seizures, a second trial of hyperventilation (done at least 10 minutes after the first trial) may have a higher yield.[3] Photic stimulation over the frequency range of at least 1 to 30 flashes per second should be used during wakefulness in appropriate patients.[4]

1.7 [MTR 3.8]

Whenever possible, recordings should include periods when the eyes are open and when they are closed. In infants over 3 months of age, passive eye closure (by placing the technologist's hand over the patient's eyes) is often successful in producing the dominant posterior rhythm, as is playing a game such as "peek-a-boo."

1.8 [MTR 3.9]

Sleep recordings should be obtained whenever possible, but not to the exclusion of the awake record. Recording the patient's EEG during drowsiness, initiation of sleep, and arousal is important, and this is best obtained with continuous EEG acquisition rather than pausing the recording in between states. Natural sleep is preferred, but sleep deprivation or melatonin may be helpful.[5] Discretion is required in choosing candidates for sleep deprivation as it may exacerbate problematic behavior in developmentally challenged patients. Use of sedation is the decision of the individual institution and physicians. The benefits of a sedated sleep recording must be weighed against the potential risks of sedation and/or its effect on the EEG.

1.9 [MTR 3.10]

The patient's clinical state (waking vs. drowsy vs. sleep) should be indicated clearly at the beginning of the recording and with each montage change. Continuous observation by the technologist, with frequent notation on the recording, is particularly important when recording young patients. This is especially true in situations during which the typical events or behaviors concerning for seizures are displayed by the patient. Whenever available, linking video to the EEG to capture these events may be helpful.

In stuporous or comatose patients and in those showing invariant EEG patterns of any kind, visual, auditory, and somatosensory stimuli should be applied systematically during the recording—but only toward the end of the recording period, lest normal sleep cycles be disrupted, or unexpected arousal-related artifact render the tracing unreadable. The stimuli and the patient's clinical responses or failure to respond should be noted on the recording as near as possible to their point of occurrence.

2. NEONATES AND YOUNG INFANTS (UP TO 4–8 WEEKS POSTTERM)

2.1 [MTR 1.1]

Recordings with at least 12 cerebral channels should be used, in addition to two, and often more, channels devoted to recording non-EEG "polygraphic" variables, such as electrocardiogram and respiration. Sixteen or more channels facilitate the necessary flexibility.

Because EEG patterns seen in the neonate are not as clearly related to stages of the wake–sleep cycle as are those of adults and older children, it is usually necessary to record polygraphic (non-EEG) variables along with the EEG to assess accurately the baby's state during the recording. Polygraphic recording is also helpful in identifying physiologic artifacts. For example, apparent monomorphic delta activity often turns out to be respiration artifact, as babies may have respiratory rates of up to 100/min. Moreover, variables other than the EEG may be directly pertinent to the patient's problems, for example, in children with apneic episodes, breathing and heart rate changes are often very important.

The parameters most frequently monitored along with EEG in infants are heart rate, respirations, and eye movements. Recording muscle activity by submental electromyography or movement transducer can also be very helpful.

Electrocardiogram should be recorded routinely and is particularly necessary when there are cardiac or respiratory problems, or when rhythmic artifacts occur.

Respirogram can be recorded by any of the following means: (1) abdominal and/or thoracic strain gauges, (2) changes in impedance between thoracic electrodes (impedance pneumogram), or (3) airway thermistors/thermocouples. In infants with respiratory problems, it is necessary to devote three or four channels to respiration to monitor both abdominal and thoracic movements, as well as airflow in the upper airway. In infants without respiratory problems, one channel of abdominal or thoracic respirogram may be sufficient.

Eye movements can be recorded by placing one electrode 0.5 cm above and slightly lateral to the outer canthus of one eye and another electrode 0.5 cm below and slightly lateral to the outer canthus of the other eye. They can be designated E1 and E2. Both lateral and vertical eye movements can be detected by linking (i.e., referring) the eye movement electrodes to auricular electrodes: E1 to A1 and E2 to A1 (or E1-A2, E2-A2).

2.2 [MTR 2.1]

Electrodes may be applied with either collodion or paste. For neonates, the fumes of acetone and ether may not be acceptable, and disk electrodes with electrolyte paste are preferable. Needle electrodes should never be used.

2.3 [MTR 2.3]

It is a matter of individual preference whether a reduced electrode array is acceptable for neonates. Some electroencephalographers prefer the full 21 electrodes of the International 10-20 system; others prefer a reduced array. It is generally agreed that a reduced array is acceptable in premature infants with small heads or where (as in neonatal intensive care units) time considerations or other circumstances may not allow application of the full electrode array. If 20 channels are available, it is possible to use standard adult 16-channel montages plus polygraphic variables.

If a reduced electrode array is used, the following electrodes (10-10 system nomenclature, with 10-20 system nomenclature in parentheses) are suggested as a minimum: Fp1, Fp2, C3, Cz, C4, T7 (T3), T8 (T4), O1, O2, Al, and A2. If a baby's earlobes are too small, mastoid leads may be substituted for A1 and A2 and can be designated Ml and M2. Acceptable alternative frontal placements in the reduced array are AF3 and AF4 instead of Fp1 and Fp2 (10-10 system nomenclature; see Guideline 2); AF3 is halfway between the Fp1 and F3 positions and AF4 halfway between the Fp2 and F4 positions.

Determining electrode sites by measurement is just as important in infants and children as in adults. Deviation from this principle is permissible only in circumstances in which it is impossible or clinically undesirable to manipulate the child's head to make the measurements. If an electrode placement must be modified because of intravenous lines, pressure bolts, scalp hematomas, and others, the homologous contralateral electrode placement should be modified similarly. If approximate rather than precise lead placement is done, the technologist should note this on the recording.

2.4 [MTR 2.4]

Electrode impedances of less than 10 kOhms are allowed to avoid excessive manipulation or excessive abrasion of tender skin. It is still important that marked differences in impedances among electrodes be avoided. Further details are in the [MTR 2.1] section.

2.5 [Guideline 3]

If a 21-electrode 10-20 system array is used, Guideline 3 recommendations should be followed as long as Cz is included. If a reduced array is used, a single montage that includes both longitudinal and transverse montages is recommended below (10-10 system nomenclature, with 10-20 system nomenclature in parentheses) (Table 1).

Note that channels 9 to 12 are a transverse bipolar chain with standard interelectrode distances rather than the double distances in channels 1 to 8. AF3 and AF4 (per 10-10 system nomenclature; see Guideline 2) may be substituted for Fp1 and Fp2, and M1 and M2 may be substituted for A1 and A2. If AF3 and AF4 are used, the reduced interelectrode distance must be taken into account when interpreting voltages in a bipolar montage.

TABLE 1. Neonatal Montage Examples

Channel	Montage A	Montage B	Montage C
1	Fpl-T7 (T3)	Fp1-C3	Fpl-T7 (T3)
2	T7 (T3)-O1	C3-O1	T7 (T3)-O1
3	Fp2-T8 (T4)	Fpl-T7 (T3)	Fp1-C3
4	T8 (T4)-O2	T7 (T3)-O1	C3-O1
5	Fp1-C3	Fp2-C4	Fp2-T8 (T4)
6	C3-O1	C4-O2	T8 (T4)-O2
7	Fp2-C4	Fp2-T8 (T4)	Fp2-C4
8	C4-O2	T8 (T4)-O2	C4-O2
9	T7 (T3)-C3	T7 (T3)-C3	T7 (T3)-C3
10	C3-Cz	C3-Cz	C3-Cz
11	Cz-C4	Cz-C4	Cz-C4
12	C4-T8 (T4)	C4-T8 (T4)	C4-T8 (T4)
13	ECG	ECG	ECG
14	Respiration	Respiration	Respiration
15	E1-A1 or A2	E1-A1 or A2	E1-A1 or A2
16	E2-A1 or A2	E2-A1 or A2	E2-A1 or A2
17	EMG	EMG	EMG

10-10 system nomenclature, with 10-20 system nomenclature in parentheses. ECG, electrocardiogram; EMG, electromyography.

The montages above are not the only permissible ones (for additional neonatal montages, see Ref. 6). Rather, they should be considered standard montages, and at least one of them should be used for at least a portion of a neonate's EEG recording in all laboratories, to provide some standardization among laboratories. Cz is always included because positive "rolandic" sharp waves (a common abnormal finding) and some seizures may only be detected at Cz in this population. Electrodes Fz, Cz and Pz are also used to visualize positive "rolandic" sharp waves.[7] Various other montages can be devised for special purposes, such as a montage combining referential and bipolar derivations.

The use of a single montage throughout the recording of a neonate may be, and often is, sufficient and is preferred in many laboratories. Nevertheless, a single montage is not always adequate. Even in laboratories preferring single montages, additional montages should be used when the need arises, for example, to delineate focal abnormalities better.

For recording polygraphic variables, the following derivations are recommended: (1) for electrocardiogram, lead 1 (right arm-left arm) is preferred; (2) for respiration, chest wall or abdomen movement (strain gauge or impedance pneumogram); (3) for eye movements (electrooculogram): E1-A1 and E2-A1 or E1-A2 and E2-A2; (4) for submental electromyography: two electrodes under the chin, each 1 to 2 cm on either side of the midline.

2.6 [MTR 3.1]

Before recording the EEGs of young inpatients, especially those in so precarious condition that the recordings must be done at the bedside, the technologist should consult with the nursing staff concerning the patient's condition and about any necessary limitations on recording procedures.

The baby's gestational age at birth, chronologic age, and postmenstrual age on the day of recording, stated in weeks, are absolutely essential to interpretation and must be included in the information available to the electroencephalographer (Postmenstrual age is gestational age plus chronological age.[8] Gestational age is the time elapsed between the first day of the last menstrual period and the day of delivery. Chronological age is the time elapsed since birth. Neonatal studies (past and present) sometimes use the term conceptional age when postmenstrual age is being measured. Some studies do not define the term conceptional age. This is an important distinction since conceptional age is the time elapsed between the day of conception and day of delivery, and therefore an infant with conceptional age of 24 weeks would have a gestational age of 26 weeks. To avoid confusing terminology, the American Academy of Pediatrics recommends using postmenstrual age and never using conceptional age.). All other available relevant clinical information (including blood gas results, serum electrolyte values, and current medications) should be noted for the electroencephalographer. If hypothermia is present, therapeutic or otherwise, it should be documented along with the patient's body temperature.

2.7 [MTR 3.3, 3.4]

In young infants' EEGs, the most appropriate sensitivity is usually 7 μV/mm, but adjustments up or down should be appropriately used to facilitate EEG interpretation. At least a portion of the recording should be run at a sensitivity adequate to display low-voltage fast activity. The low-frequency filter setting should be between 0.3 and 0.6 Hz (−3 dB) (time constants of 0.27–0.53 second), not the commonly used 1 Hz (0.16 second).

For electrooculogram, a sensitivity of 7 μV/mm and the same time constant as for the concomitantly recorded EEG derivations are recommended. For respirogram, amplification should be adjusted to yield a clearly visible vertical deflection. A low-frequency filter setting of 0.3 to 0.6 Hz, but not direct current, should be used. For the submental electromyography recording, a sensitivity of 3 μV/mm, a low-frequency filter setting of about 5 Hz (time constant of about 0.03 second), and a high-frequency filter setting of 70 Hz should be used.

2.8 [MTR 3.7, 3.8, 3.9]

If possible, it is advantageous to schedule the EEG at feeding time and arrange to feed the child after the electrodes have been applied but before beginning the recording, as babies tend to sleep after feeding.

Extra recording time should be allotted for neonatal EEGs. Time is commonly lost because of a greater number of movement and other physiologic artifacts during wakefulness, and extra time is usually needed to obtain a recording sufficient to permit the evaluation of stages of the wake–sleep cycle and other states.

Except when the EEG is grossly abnormal, 20- or 30-minute recordings are usually insufficient. In neonates with invariant patterns, it may be necessary to obtain at least 60 minutes of recording to demonstrate that the tracings are not likely to change. When there is EEG variability, adequate sampling of both major sleep states is important. The initial sleep state in the neonate is usually active sleep, which may last a very short time or continue for many minutes. An adequate sleep tracing must include a full epoch of quiet sleep. It is never necessary or desirable to use sedation to obtain a sleep recording in a neonate.

Repetitive photic stimulation is rarely, if ever, clinically useful in neonates and is not recommended.

2.9 [MTR 3.10]

The child's condition, including head and eyelid position, should be clearly indicated at the beginning of every montage. Continuous observations by the technologist, with frequent notation on the recording, are particularly important when recording from neonates.

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. ACNS 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 in order 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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