American Clinical Neurophysiology

Guideline Two: Minimum Technical Standards for Pediatric Electroencephalography

Introduction

These guidelines for clinical pediatric EEG should be considered in conjunction with the more general Guideline 1: Minimum Technical Requirements for Performing Clinical Electroencephalography (MTR).

The basic principles of clinical EEG outlined in the MTR also apply to the very young and are reaffirmed. However, special considerations are pertinent to pediatric recordings and are discussed below. The numbers in parentheses in this Guideline refer specifically to sections of the MTR that must be modified in these special situations. Where a subject is not covered here, the recommendations of Guideline 1 remain appropriate and should be consulted.

Emphasis here will be on EEG in neonates, infants, and young children, since recording the EEGs of 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.

1. Children

1.1 (**MTR 2.1)** Because children, especially young children, have a tendency to move a good deal during recording, 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. The inverted saucer-shaped silver-silver chloride electrode with a small hole for the injection of electrolyte solution is best. Needle electrodes are not needed and should not be used.

1.2 (MTR 2.3) All 21 electrodes of the International 10-20 System (Jasper HH, 1958) should be used for most purposes. The standard montages used for adults should be used for children.

1.3 (MTR 3.2) Before recording the EEGs of young inpatients, especially those in so precarious a condition that the recordings must be done at bedside, the technician should consult with the nursing staff concerning the patient's condition and any limitations on recording procedures.

1.4 (MTR 3.4) 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) should be used. However, 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.

1.5 (MTR 3.9) Photic stimulation over the frequency range of at least 1—20 flashes/s should be used during wakefulness in appropriate patients.

1.6 (MTR 3.10) 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 technician's hand over the patient's eyes) is often successful in producing the dominant posterior rhythm, as is the playing of game such as peek-a-boo.

1.7 (MTR 3.12) Sleep recordings should be obtained whenever possible, but not to the exclusion of the awake record. The recording of the patient during drowsiness, initiation of sleep, and arousal is important. Natural sleep is preferred, but if the use of sedation is necessary, all efforts should still be made to record arousal at the end of the recording.
1.8 (MTR 3.13) The patient's condition should be clearly indicated at the beginning of the recording from every montage. Continuous observation by the technician, with frequent notations on the recording, is particularly important when recording young patients.

2. Neonates and Young Infants (Up to 4-8 Weeks Post-Term)

2.1 (MTR 1.1) Instruments with at least 16 channels should be used. Two, and often more, channels must be devoted to recording non-EEG "polygraphic" variables, such as EKG and respiration. Sixteen or more channels allow 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 in order 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, since 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 those experiencing apneic episodes, breathing and heart rate changes are most relevant.

The parameters most frequently monitored along with EEG in infants are respirations, eye movements, and heartbeats. A recording of muscle movements, by submental electromyography (EMG) or movement transducer, also can be quite helpful.

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 in order to monitor both abdominal and thoracic movements, plus airflow in the upper airway. In infants without respiratory problems, one channel of abdominal or thoracic respirogram may be sufficient.

For recording eye movements, one electrode should be placed 0.5 cm above and slightly lateral to the outer canthus of one eye and another 0.5 cm below and slightly lateral to the outer canthus of the other eye. These can be designated E1 and E2. Both lateral and vertical eye movements can be detected by linking (referring) eye movement to auricular electrodes: E1 to A1 and E2 to A1 (or E1-A2, E2-A2).

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

2.2 (MTR 2.1) Electrodes may be applied with either collodion or paste. The inverted saucer-shaped silver-silver chloride electrode with a small hole for the injection of electrolyte solution is best. 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 or not a reduced array is routinely acceptable for neonates. Some electroencephalographers prefer the full 10—20 array; 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 or other

circumstances may not allow application of the full array. However, if 20 channels are available, it is possible to use standard adult 16-channel montages plus polygraphic variables.

The following electrodes are suggested as a minimum reduced array: 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 and can be designated Ml and M2. Acceptable alternative frontal placements in the reduced array are Fp3 and Fp4 instead of Fp1 and Fp2. Fp3 and Fp4 are halfway between the Fp1 and F3, and the Fp2 and F4 positions, respectively. (Note that the use of Fp3 and Fp4 makes for unequal interelectrode distances in scalp-scalp montages.)

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 due to intravenous lines, pressure bolts, scalp hematomas, and the like, the homologous contralateral electrode placement should be similarly modified. If no measurements are made, the technologist should note this on the recording.

2.4 (MTR 2.4) Electrode impedances of less than 5 KOhms can be obtained regularly, although higher impedances may be allowed in order to avoid excessive manipulation or excessive abrasion of tender skin. It is most important that marked differences in impedances among electrodes be avoided.

2.5 (MTR3.1) In neonates in whom two or more channels must be devoted to polygraphic variables, the following montages are recommended:

Channel	A	B	C
1	Fpl-F3	Fpl-A1	FP1-C3
2	F3-C3	Fp2-A2	C3-01
3	C3-P3	F3-A1	Fpl-T3
4	Fp2-F4	F4-A2	T3-01
5	F4-C4	C3-A1	Fp2-C4
6	C4-P4	C4-A2	C4-02
7	F7-T3	P3-A1	Fp2-T4
8	T3-T5	P4-A2	T4-02
9	T5-01	01-A1	T3-C3
10	F8-T4	02-A2	C3-Cz
11	T4-T6	T3-A1	Cz-C4
12	T6-02	T4-A2	C4-T4

These are based on the assumption that a 16-channel instrument is used with 4 channels devoted to polygraphic variables, leaving 12 channels for EEG. Montages A and B are for full 10-20 System electrode arrays: Montage C for the reduced array. In Montages B and C, Fp3 and Fp4 may be substituted for Fp1 and Fp2 and M1 and M2 may be substituted for A1 and A2.

It is not implied that the above montages are the only ones that can be used. 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. Since Montage C includes the midline, it can be particularly helpful when recording premature infants. In any case, Cz should always be included because positive "rolandic" sharp waves (a common pathologic finding) may occur only in Cz in this population. Various other montages can be devised for special purposes. Even a montage combining referential and scalp-scalp derivations is acceptable for neonatal EEGs.

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

For recording polygraphic variables, the following derivations are recommended: (1) For eye movements (EOG): use E1-A1 and E2-A1 or E2-A1 and E1-A2. (2) For submental EMG: two electrodes under the chin, each 1-2 cm. on either side of the midline. (3) For EKG, lead 1 (right arm-left arm) is preferred. If submental EMG is being recorded and if only heart rate is of interest, the EKG channel can often by omitted because the R wave is usually visible in the EMG channel.

2.6 (MTR 3.2) Before recording the EEGs of inpatients, especially those in so precarious a condition that the recording must be done at bedside, the technician should consult with the nursing staff concerning the patient's condition and any limitations on recording procedures.

The baby's gestational age at birth and conceptional age (gestational age at birth plus time since birth) on the day of recording, stated in weeks, are absolutely essential to interpretation and must be included, together with chronological age since birth in the information available to the electroencephalographer. All other available relevant clinical information (including concentration of blood gases, serum electrolyte values, and current medications) should be noted for the electroencephalographer's use.

2.7 (MTR 3.4). In young infants' EEGs, the most appropriate sensitivity is usually 7 uV/mm, but adjustments up or down are more often needed than in the case of older patients. 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 s), not the commonly used 1 Hz (0.16 s).

For EOG, a sensitivity of 7 uV/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, and a low-frequency filter setting of 0.3-0.6 Hz, but not direct current (DC), should be used. For the submental EMG recording, a sensitivity of 3 uV/mm, a low-frequency filter setting of about 5 Hz (time constant of about 0.03 s), and a high-frequency filter setting of 70 Hz should be employed.

2.8 (MTR 3.9, 3.12). 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 feedings.

Allow for extra recording time for the EEGs of neonates. Time is commonly lost due to a greater number of movement and other physiologic artifacts during wakefulness, and extra time is usually needed in order to obtain sufficient recording to permit evaluation of stages of the wake-sleep cycle and other states.

Except when the EEG is grossly abnormal, 20- or 30-min. recordings are usually insufficient. In those neonates in whom patterns appear to be invariant, it may be necessary to obtain at least 60 min. of recording to demonstrate that the tracings are not likely to change. In the rest, 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 episode 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 3.13) 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 notations on the recording, are particularly important when recording from neonates.

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 recording, but only toward the end of the recording period, lest normal sleep cycles be disrupted or unexpected arousal-produced artifact render the tracings unreadable thereafter. 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.

REFERENCE

1. Jasper HH. The ten-twenty electrode system of the International Federation. *Electroencephalogr Clin Neurophysiol 1958; to:* 371—3.

