

American Clinical Neurophysiology Society Guideline 3: A Proposal for Standard Montages to Be Used in Clinical EEG

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Summary: This revision to the EEG Guidelines is an update incorporating current electroencephalography technology and practice and was previously published as Guideline 6. A discussion of methodology for the appropriate selection of reference electrodes is added. In addition, montages are added to assist with localization of

abnormal activity in mesial frontal and anterior temporal regions.

Key Words: Electroencephalography montage, 10-10 system, International 10-20 system, Adult, Pediatric.

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Montages are logical and orderly arrangements of channels (electrode pairs, with waveforms representing the potential difference between the two electrodes) that display EEG activity over the entire scalp, allow comparison of activity on the two sides of the brain (lateralization), and aid in localization of recorded activity to a specific brain region. With 21 electrode positions in the 10-20 system and 16 channels, the number of possible montages is 21.¹⁶ The 10-10 system, with more than 70 electrode positions, and the ability to display up to 256 channels in modern digital EEG machines, provides the ability to create an even greater number of montages. However, from a clinical and practical standpoint, only a limited number of montages need to be used during a recording session.

A great diversity of montages exists among different EEG laboratories, but many of these montages fail to display the EEG adequately or are inordinately complex. Moreover, this diversity impedes interchange of information among electroencephalographers, to the ultimate detriment of patient care.

Recognizing the need for improving this aspect of EEG practice, the montages listed in this Guideline are recommended for standard use by clinical laboratories. This proposal should not be construed as an attempt to limit the total number of montages used by any EEG laboratory. Indeed, depending on individual recording circumstances, additional montages may be necessary for an adequate EEG examination and for the solution of particular problems. The proposed montages are intended to constitute a basic minimum, not a maximum, for general-purpose use. If these recommendations are adopted widely, communication among electroencephalographers should be facilitated.

Montages using additional electrode positions described in the 10-10 system are particularly useful during video-EEG monitoring, especially in patients with suspected temporal or

frontal lobe epilepsy, but can also be helpful for routine EEG recording. This Guideline provides some suggested montages for use in these situations.

However, the proposed montages are not designed for other special purposes, such as for neonatal EEGs, all-night sleep recordings, or for verification of electrocerebral inactivity.

1. Montage Designations

1.1 The class of montage is designated as follows: longitudinal bipolar (LB), transverse bipolar (TB), or referential (R). (Bipolar derivations are also sometimes called “differential”).

1.2 The numeral to the left of the point indicates the number of channels. Montages are designed for 16, 18, and 20 channels.

1.3 The numeral two or three to the right of the point indicates an alternative montage of the same class for a particular size of instrument (e.g., LB-16.2 and LB-16.3 are alternative for LB-16.1). The number of alternatives has been limited to a maximum of three.

2. Recommendations Governing Selection of the Proposed Montages with Explanatory Notes

2.1 The Committee *reaffirms* the statements pertaining to montages set forth previously in the Guidelines of the American Clinical Neurophysiology Society (ACNS) and that are paraphrased as follows:

- (a) that no less than 16 channels of simultaneous recording be used, and that a larger number of channels be encouraged,
- (b) that the full 21 electrode placements of the 10-20 system be used,
- (c) that both bipolar and referential montages be used for clinical interpretation,
- (d) that the electrode derivations of each channel be clearly identified at the beginning of each montage,
- (e) that the pattern of electrode connections be made as simple as possible, and that montages should be easily comprehended,
- (f) that the electrode pairs (bipolar) preferentially should run in straight (unbroken) lines and the interelectrode distances kept equal,

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(g) that tracings from the more anterior electrodes be placed above those from the more posterior electrodes on the recording page, and

(h) that it is very desirable to have some of the montages comparable for all EEG laboratories.

In addition, a single channel electrocardiogram (ECG) should be included on one EEG channel. This is helpful to distinguish between epileptiform discharges and ECG artifact, and to identify pulse artifact.

2.2 The Committee recommends a “left above right” order of derivations, i.e., on the recording page, left-sided leads should be placed above right-sided leads for either alternating pairs of derivations or blocks of derivations. This recommendation coincides with the prevailing practice of most EEG laboratories, at least in North America and in many other areas.

2.3 A maximum number of electrodes should be represented in each montage, within limitations imposed by the number of recording channels, to ensure adequate coverage of head areas.

2.4 Three classes of montage should be represented in each recording in the following: LB, TB, and R.

2.5 For 16- and 18-channel recording, one montage from each of the 3 classes will be needed (Table 1).

2.6 If 20 channels are available, 2 channels of polygraphic variables may be added to the 18-channel bipolar montages, and a reference to Cz in between those to Fz and Pz.

For adequate mapping of electrical fields, additional montages may need to be devised that include LB and TB chains recorded simultaneously.

In the montages listed for R recording, mastoid leads may be substituted for A1 and A2 and can be designated as M1 and M2.

Potential pitfalls in referential recording are numerous, and caution should be exercised if unwanted activity appears in a reference lead. In such instances, another reference should be chosen, and the change should be clearly noted in the recording. Common alternative choices of reference include Cz and an average constructed from all electrodes on the head. In average reference recording, the prefrontal electrodes, Fp1 and Fp2, and anterior temporal electrodes, F7 and F8, are often omitted from the average to reduce contamination by eye movement artifact.

2.7 A logical order of arrangement should prevail in each montage and in comparable montages designed for instruments of different sizes.

Recognizing the fact that experienced electroencephalographers differ for valid reasons in their approach to the display of EEG activity, alternative sets of montages have been included in the

recommendations. Further details about the principles of montage design and the different preferences by members of this Committee have been published (*Am J EEG Technol*, 17: Nos. 1 and 2, 1977).

In general, the LB.1 and the R.1 series consist of leads grouped in anatomical proximity extending sequentially across the head from left to right. In this system, hemispheric differences are readily appreciated. In the LB.2 and LB.3 series, blocks of homologous derivations are compared (LB.2 extending from the midline sagittal region laterally, LB.3 extending from lateral regions medially). The alternative montages in the TB series depend, in part, on the extent of polar coverage. In the R.2 and R.3 series, homologous derivations are juxtaposed in adjacent channels to facilitate comparison of localized regions (R.2 extending from the midline sagittal region laterally and R.3 extending from the lateral regions medially).

Regarding referential montages, the choice of reference is critically important. A midline electrode (such as Cz) would be a better choice of reference than A1 or A2 if temporal lobe epilepsy is suspected, as the field of a temporal epileptiform discharge often involves A1 or A2 (see the suggested Cz referential montages in Appendix 6 below). Also, A1/A2 electrodes tend to be frequently contaminated with artifact. However, a Cz reference would not be a good choice if there is prominent sleep activity or abnormalities are noted predominantly in sleep. An ear reference would be more suitable than Cz in the delineation of a frontal focus.

Minor modifications of the recommended montages may be instituted during part of the recording, especially for monitoring other physiologic variables (such as tremor or respiration), if the modifications do not infringe on the principles set forth in these recommendations.

When electrode positions from the 10-10 system or sphenoidal electrodes are used in the recording, either bipolar or referential montages can be used. If only selected electrode positions from the 10-10 system (such as FT9/FT10 or FC1/FC2) are added to the 10-20 system, instead of the entire set of 10-10 electrodes, it may result in unequal interelectrode distances. Nevertheless, bipolar montages can provide valuable localizing information. For instance, F7/F8 electrodes record activity from both anterior temporal and frontal regions. A bipolar montage using FT9/FT10 (or sphenoidal electrodes) can localize activity more precisely to the anterior temporal region (see the suggested anterior temporal montages in Appendix 2 below). Similarly, montages that include closely spaced parasagittal electrodes (FC1/FC2, FCz, C1/C2, CP1/CP2, and CPz) can be very helpful in patients with suspected mesial frontal lobe epilepsy (see the suggested transverse frontal montage in Appendix 4 below).

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. The American Clinical Neurophysiology Society (ACNS) recognizes that specific patient care decisions are the prerogative of the patient and the physician caring for the patient, based on all the circumstances involved. The clinical context section is made available to place the evidence-based guidelines into perspective with current practice habits and challenges. Formal practice recommendations are not intended to replace clinical judgment.

TABLE 1. Number of Montages Recommended

No. Channels	Longitudinal Bipolar	Transverse Bipolar	Referential	Total
20	1 (3)	1 (2)	1 (3)	3
18	1 (3)	1 (2)	1 (3)	3
16	1 (3)	1 (3)	1 (3)	3

Figures in parentheses refer to the number of alternative montages proposed.

APPENDIX 1. Standard Longitudinal Bipolar (LB) Montages*

Channel No.	LB-18.1	LB-18.2	LB-18.3	LB-16.1	LB-16.2	LB-16.3
1	Fp1-F7	Fz-Cz	Fp1-F7	Fp1-F7	Fp1-F3	Fp1-F7
2	F7-T7 (T3)	Cz-Pz	F7-T7 (T3)	F7-T7 (T3)	F3-C3	F7-T7 (T3)
3	T7 (T3)-P7 (T5)	Fp1-F3	T7 (T3)-P7 (T5)	T7 (T3)-P7 (T5)	C3-P3	T7 (T3)-P7 (T5)
4	P7 (T5)-O1	F3-C3	P7 (T5)-O1	P7 (T5)-O1	P3-O1	P7 (T5)-O1
5	Fp1-F3	C3-P3	Fp2-F8	Fp1-F3	Fp2-F4	Fp2-F8
6	F3-C3	P3-O1	F8-T8 (T4)	F3-C3	F4-C4	F8-T8 (T4)
7	C3-P3	Fp2-F4	T8 (T4)-P8 (T6)	C3-P3	C4-P4	T8 (T4)-P8 (T6)
8	P3-O1	F4-C4	P8 (T6)-O2	P3-O1	P4-O2	P8 (T6)-O2
9	Fz-Cz	C4-P4	Fp1-F3	Fp2-F4	Fp1-F7	Fp1-F3
10	Cz-Pz	P4-O2	F3-C3	F4-C4	F7-T7 (T3)	F3-C3
11	Fp2-F4	Fp1-F7	C3-P3	C4-P4	T7 (T3)-P7 (T5)	C3-P3
12	F4-C4	F7-T7 (T3)	P3-O1	P4-O2	P7 (T5)-O1	P3-O1
13	C4-P4	T7 (T3)-P7 (T5)	Fp2-F4	Fp2-F8	Fp2-F8	Fp2-F4
14	P4-O2	P7 (T5)-O1	F4-C4	F8-T8 (T4)	F8-T8 (T4)	F4-C4
15	Fp2-F8	Fp2-F8	C4-P4	T8 (T4)-P8 (T6)	T8 (T4)-P8 (T6)	C4-P4
16	F8-T8 (T4)	F8-T8 (T4)	P4-O2	P8 (T6)-O2	P8 (T6)-O2	P4-O2
17	T8 (T4)-P8 (T6)	T8 (T4)-P8 (T6)	Fz-Cz	ECG	ECG	ECG
18	P8 (T6)-O2	P8 (T6)-O2	Cz-Pz			
19	ECG	ECG	ECG			

*10-10 electrode position nomenclature with 10-20 nomenclature in parentheses.

APPENDIX 2. Standard Transverse Bipolar (TB) Montages*

Channel No.	TB-18.1	TB-18.2	TB-16.1	TB-16.2	TB-16.3
1	F7-Fp1	Fp1-Fp2	F7-Fp1	Fp1-Fp2	F7-Fp1
2	Fp1-Fp2	F7-F3	Fp1-Fp2	F7-F3	Fp2-F8
3	Fp2-F8	F3-Fz	Fp2-F8	F3-Fz	F7-F3
4	F7-F3	Fz-F4	F7-F3	Fz-F4	F3-Fz
5	F3-Fz	F4-F8	F3-Fz	F4-F8	Fz-F4
6	Fz-F4	A1-T7 (T3)	Fz-F4	A1-T7 (T3)	F4-F8
7	F4-F8	T7 (T3)-C3	F4-F8	T7 (T3)-C3	T7 (T3)-C3
8	T7 (T3)-C3	C3-Cz	T7 (T3)-C3	C3-Cz	C3-Cz
9	C3-Cz	Cz-C4	C3-Cz	Cz-C4	Cz-C4
10	Cz-C4	C4-T8 (T4)	Cz-C4	C4-T8 (T4)	C4-T8 (T4)
11	C4-T8 (T4)	T8 (T4)-A2	C4-T8 (T4)	T8 (T4)-A2	P7 (T5)-P3
12	P7 (T5)-P3	P7 (T5)-P3	P7 (T5)-P3	P7 (T5)-P3	P3-Pz
13	P3-Pz	P3-Pz	P3-Pz	P3-Pz	Pz-P4
14	Pz-P4	Pz-P4	Pz-P4	Pz-P4	P4-P8 (T6)
15	P4-P8 (T6)	P4-P8 (T6)	P4-P8 (T6)	P4-P8 (T6)	P7 (T5)-O1
16	P7 (T5)-O1	O1-O2	O1-O2	O1-O2	O2-P8 (T6)
17	O1-O2	Fz-Cz	ECG	ECG	ECG
18	O2-P8 (T6)	Cz-Pz			
19	ECG	ECG			

*10-10 electrode position nomenclature with 10-20 nomenclature in parentheses.

APPENDIX 3. Standard Referential Montages—Ear Reference*

Channel No.	R-18.1	R-18.2	R-18.3	R-16.1	R-16.2	R-16.3
1	F7-A1	Fz-A1	F7-A1	F7-A1	Fp1-A1	F7-A1
2	T7 (T3)-A1	Pz-A1	F8-A2	T7 (T3)-A1	Fp2-A2	F8-A2
3	P7 (T5)-A1	Fp1-A1	T7 (T3)-A1	P7 (T5)-A1	F3-A1	T7 (T3)-A1
4	Fp1-A1	Fp2-A2	T8 (T4)-A2	Fp1-A1	F4-A2	T8 (T4)-A2
5	F3-A1	F3-A1	P7 (T5)-A1	F3-A1	C3-A1	P7 (T5)-A1
6	C3-A1	F4-A2	P8 (T6)-A2	C3-A1	C4-A2	P8 (T6)-A2
7	P3-A1	C3-A1	Fp1-A1	P3-A1	P3-A1	Fp1-A1
8	O1-A1	C4-A2	Fp2-A2	O1-A1	P4-A2	Fp2-A2
9	Fz-A1	P3-A1	F3-A1	Fp2-A2	O1-A1	F3-A1
10	Pz-A2	P4-A2	F4-A2	F4-A2	O2-A2	F4-A2
11	Fp2-A2	O1-A1	C3-A1	C4-A2	F7-A1	C3-A1
12	F4-A2	O2-A2	C4-A2	P4-A2	F8-A2	C4-A2
13	C4-A2	F7-A1	P3-A1	O2-A2	T7 (T3)-A1	P3-A1
14	P4-A2	F8-A2	P4-A2	F8-A2	T8 (T4)-A2	P4-A2
15	O2-A2	T7 (T3)-A1	O1-A1	T8 (T4)-A2	P7 (T5)-A1	O1-A1
16	F8-A2	T8 (T4)-A2	O2-A2	P8 (T6)-A2	P8 (T6)-A2	O2-A2
17	T8 (T4)-A2	P7 (T5)-A1	Fz-A1	ECG	ECG	ECG
18	P8 (T6)-A2	P8 (T6)-A2	Pz-A2			
19	ECG	ECG	ECG			

*10-10 electrode position nomenclature with 10-20 nomenclature in parentheses.

APPENDIX 4. Suggested Longitudinal Bipolar Anterior Temporal (LBAT) Montages*

Channel No.	LBAT 20.1	LBAT 20.2	LBAT 20.3
1	Fp1-F7	Fz-Cz	Fp1-F7
2	†F7-FT9	Cz-Pz	†F7-FT9
3	†FT9-T7 (T3)	Fp1-F3	†FT9-T7 (T3)
4	T7 (T3)-P7 (T5)	F3-C3	T7 (T3)-P7 (T5)
5	P7 (T5)-O1	C3-P3	P7 (T5)-O1
6	Fp1-F3	P3-O1	Fp2-F8
7	F3-C3	Fp2-F4	†F8-FT10
8	C3-P3	F4-C4	†FT10-T8 (T4)
9	P3-O1	C4-P4	T8 (T4)-P8 (T6)
10	Fz-Cz	P4-O2	P8 (T6)-O2
11	Cz-Pz	Fp1-F7	Fp1-F3
12	Fp2-F4	†F7-FT9	F3-C3
13	F4-C4	†FT9-T7 (T3)	C3-P3
14	C4-P4	T7 (T3)-P7 (T5)	P3-O1
15	P4-O2	P7 (T5)-O1	Fp2-F4
16	Fp2-F8	Fp2-F8	F4-C4
17	†F8-FT10	†F8-FT10	C4-P4
18	†FT10-T8 (T4)	†FT10-T8 (T4)	P4-O2
19	T8 (T4)-P8 (T6)	T8 (T4)-P8 (T6)	Fz-Cz
20	P8 (T6)-O2	P8 (T6)-O2	Cz-Pz
21	ECG	ECG	ECG

*10-10 electrode position nomenclature with 10-20 nomenclature in parentheses.
†Alters interelectrode distance.

APPENDIX 5. Suggested Transverse Frontal Montage*

1. Fp1-Fp2
2. F7-F3
3. F3-Fz
4. Fz-F4
5. F4-F8
6. †FC1-FCz
7. †FCz-FC2
8. T7 (T3)-C3
9. †C3-C1
10. †C1-Cz
11. †Cz-C2
12. †C2-C4
13. C4-T8 (T4)
14. †CP1-CPz
15. †CPz-CP2
16. P7 (T5)-P3
17. P3-Pz
18. Pz-P4
19. P4-P8 (T6)
20. O1-O2
21. ECG

*10-10 electrode position nomenclature with 10-20 nomenclature in parentheses.
†Alters interelectrode distance.

APPENDIX 6. Suggested Referential Montages—Cz Reference*

Channel No.	R-18.1	R-18.2	R-18.3	R-16.1	R-16.2	R-16.3
1	F7-Cz	Fz-Cz	F7-Cz	F7-Cz	Fp1-Cz	F7-Cz
2	T7 (T3)-Cz	Pz-Cz	F8-Cz	T7 (T3)-Cz	Fp2-Cz	F8-Cz
3	P7 (T5)-Cz	Fp1-Cz	T7 (T3)-Cz	P7 (T5)-Cz	F3-Cz	T7 (T3)-Cz
4	Fp1-Cz	Fp2-Cz	T8 (T4)-Cz	Fp1-Cz	F4-Cz	T8 (T4)-Cz
5	F3-Cz	F3-Cz	P7 (T5)-Cz	F3-Cz	C3-Cz	P7 (T5)-Cz
6	C3-Cz	F4-Cz	P8 (T6)-Cz	C3-Cz	C4-Cz	P8 (T6)-Cz
7	P3-Cz	C3-Cz	Fp1-Cz	P3-Cz	P3-Cz	Fp1-Cz
8	O1-Cz	C4-Cz	Fp2-Cz	O1-Cz	P4-Cz	Fp2-Cz
9	Fz-Cz	P3-Cz	F3-Cz	Fp2-Cz	O1-Cz	F3-Cz
10	Pz-Cz	P4-Cz	F4-Cz	F4-Cz	O2-Cz	F4-Cz
11	Fp2-Cz	O1-Cz	C3-Cz	C4-Cz	F7-Cz	C3-Cz
12	F4-Cz	O2-Cz	C4-Cz	P4-Cz	F8-Cz	C4-Cz
13	C4-Cz	F7-Cz	P3-Cz	O2-Cz	T7 (T3)-Cz	P3-Cz
14	P4-Cz	F8-Cz	P4-Cz	F8-Cz	T8 (T4)-Cz	P4-Cz
15	O2-Cz	T7 (T3)-Cz	O1-Cz	T8 (T4)-Cz	P7 (T5)-Cz	O1-Cz
16	F8-Cz	T8 (T4)-Cz	O2-Cz	P8 (T6)-Cz	P8 (T6)-Cz	O2-Cz
17	T8 (T4)-Cz	P7 (T5)-Cz	Fz-Cz	ECG	ECG	ECG
18	P8 (T6)-Cz	P8 (T6)-Cz	Pz-Cz			
19	ECG	ECG	ECG			

*10-10 electrode position nomenclature with 10-20 nomenclature in parentheses.